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Essays in Sovereign Default and Central Banking

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by
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Dedicated to my family.

ABSTRACT OF THE DISSERTATION

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The recent phenomenon of debt redemption is posing new challenges in emerging economies, which are typically characterized by high levels of sovereign default risk. How do sovereign default risk and sovereign debt affect central bank independence? And how does this affect reserve accumulation in these countries? In the first chapter of this dissertation I study how business cycle fluctuations affect sovereign debt and sovereign default risk and how the de facto central bank independence is endogenously determines in emerging economies. I build a sovereign default model in which, period-by-period, the fiscal authority determines the degree of independence of the monetary authority in order to obtain the desired level of inflation. In the model, lower GDP triggers higher sovereign debt and default risk, causing a deterioration of the de facto central bank independence and higher inflation. I show that institutional arrangements aiming at leaving the central bank independent are welfare improving. In the second chapter I analyze how higher central bank independence affects the reserve accumulation in emerging economies and explain the disinflation process observed in the last 20 years. I develop a dual authority sovereign default in which the fiscal authority issues defaultable debt and the monetary authority accumulates reserves and determines the inflation rate of the period. In the model I show how higher central bank independence improves the reserves accumulation for consumption smoothing purposes. In addition, and conditional on the calibration of the model, the higher reserve accumulation can explain the decline in the observed inflation rate, due to a decline in its marginal benefit through lower marginal utility of consumption.

Chapter 1: De facto central bank independence in emerging economies with sovereign default risk

In this paper I study the endogenous determination of *de facto* central bank independence through the strategic interaction between monetary and fiscal authorities in a standard sovereign default model, in which debt is denominated in local currency. The model is calibrated to replicate moments of Brazil's data and I find that *de facto* central bank independence is lower for higher levels of debt and spread and for lower levels of GDP. The model replicates the pattern of the 2015 Brazilian recession, showing a deterioration of *de facto* central bank independence triggered by higher debt and spreads. I find that an economy with fully independent central bankers is characterized by lower inflation and substantially higher levels of debt and sovereign spreads.

1.1 Introduction

In the last 20 years most emerging economies have managed to increase their share of debt denominated in local currency[1]. The implemented reforms[2] increased the *de jure* central bank independence in these countries, with levels that are now comparable to those of the advanced economies. Despite these reforms, the inflation rates observed in emerging economies are still higher than advanced countries[3] and correlated with fiscal variables such as sovereign spread and debt. This evidence suggests that the *de facto*, i.e. the actual, level of central bank independence may differ substantially from the *de jure* level. What is the actual level of central bank independence in emerging economies? Are the higher levels of inflation explained by debt dilution? If so, is debt dilution a determinant

[1] Historically, emerging economies used to issue debt denominated in foreign currency, a phenomenon called *original sin*.

[2] See [1] for a more detailed explanation.

[3] Over the period 2000-2020 the average and the standard deviation of the inflation rate in emerging economies are, respectively, 6% and 1.3%, while in advanced economies these values are 1.7% and 0.8%.

of the *de facto* central bank independence? To answer these questions I develop a quantitative sovereign default model with endogenous choice of central bank independence that can account for most of the moments observed for Brazil, a country that experienced debt redemption and managed to lower inflation over the period 2000-2020. I show that *de facto* independence tends to decline for higher levels of debt and sovereign default risk and in years of economic downturn. Moreover, I find that an institutional environment aimed at sustaining the central bank fully independent may be welfare-improving.

In many emerging economies debt redemption[4] is a recent trend that has been documented in the literature[5]. While debt denominated in foreign currency represents a real burden of payment for governments, debt denominated in local currency can be diluted through nominal exchange rate devaluations and inflation. Less independent central banks are more likely to internalize fiscal constraints in the conduct of monetary policy through higher inflation, abandoning (at least partially) their price stabilization mandate.

Conventional measures of Central Bank Independence (CBI) capture *de jure* independence, i.e. legal and institutional features such as the length of the mandate of the central bank chairman and the degree of operational and financial autonomy of the central bank, among others. Unfortunately, these measures do not seem to be satisfactory at accounting for *de facto* central bank independence[6], as many emerging economies have central banking systems that are formally independent but in practice are vulnerable to political pressure. Reliable indicators of *de facto* central bank independence are lacking, given the difficulty associated with measuring the behavior of central banks in relation with their mandates.

In more detail, to shed light on the endogenous choice of central bank independence I construct

[4]Debt redemption is typically defined as the shift from issuing foreign-denominated to domestically-denominated bonds.

[5]See [2] and [3] for instance.

[6]*De facto* central bank independence can be thought as the *actual* degree of independence, i.e. how central bankers act independently from political interference.

a sovereign default model[7] with incomplete markets in which two authorities interact in determining the optimal policies: a monetary and a fiscal authority. The two authorities have different objectives and tools available and their strategic interaction determines the equilibrium of the economy. I assume that the two authorities operate in a sequentially strategic environment in which the fiscal authority moves first and the monetary authority moves second. The monetary authority is run by a central banker, who lives one period, and is appointed by the fiscal authority. Different central banker types differ in their preferences over consumption and inflation: a more independent central banker will be concerned by inflation stabilization while a more controlled central banker will take into account consumption and fiscal dynamics as well. Once the central banker is appointed by the fiscal authority, it will determine the optimal inflation rate for her term. The fiscal authority moves first, taking into account the best inflation response of all different types of central bankers, and it appoints the central banker type that maximizes its value function. I assume that appointing a less independent central banker is costly for the fiscal authority in terms of reputation[8]. Therefore the fiscal authority faces a tradeoff between a more controlled central banker, incurring in large losses of reputation but enjoying more favorable policies, and a more independent central banker, who improves its reputation but is less favorable in terms of desired inflation. The fiscal authority can issue defaultable long-period debt to foreign investors, as it is common in sovereign default models, and is denominated in units of domestic currency.

In the model, the optimal level of inflation is determined by the degree of *de facto* central bank independence, i.e. the central banker type appointed by the fiscal authority, as well as other economic fundamentals. More independent central bankers tend to attain lower inflation levels than more controlled ones. I find that inflation increases the higher is the outstanding level of debt. The presence of long-period bonds partially mitigates inflationary pressures as higher debt dilution would imply a higher level of debt issuance at unfavorable prices by the fiscal authority. Moreover, the degree of *de facto* central bank independence distorts the optimal borrowing choice of the fiscal

[7]See [4], [5], [6] for reference on sovereign default models.
[8]I model this choice with a standard cost function.

authority in two opposite directions: firstly, by inducing underborrowing caused by insufficient debt dilution in the current period and, secondly, by inducing overborrowing caused by expectations of excessive debt dilution in the future.

I then solve the model numerically to evaluate its quantitative predictions regarding the levels of inflation, public debt, sovereign spreads and correlations between inflation and fiscal variables. The model matches most of the moments of interest of Brazilian data and can accurately account for the level of inflation and its correlation with sovereign spread. I also find central bank independence to be procyclical, i.e. positively correlated with GDP, and it correlates negatively with the outstanding stock of debt and sovereign spread. By analyzing the dynamic response of the model to output shocks I find that in bad times the fiscal authority increases the degree of control over the monetary authority in order to obtain higher inflation rates that can partially dilute the debt increase caused by the initial negative shock.

In addition, I perform an event analysis to compare the performance of the model with the 2015 Brazilian recession. The model replicates the increase in debt and sovereign spreads determined by the recession and displays a reduction in *de facto* central bank independence that caused an inflation spike. I also perform a counterfactual analysis of the 2015 recession, by comparing the baseline economy with a model with no option of control. In the alternative model, while we do not observe changes in the *de facto* level of independence, debt would have risen more and sovereign spreads would have been almost 70% higher than the baseline economy.

Moreover, I compare the results of the baseline model with an economy in which the central banker is fully independent from pressures from the fiscal authority and I show that in such an economy, while inflation would be mitigated, the government would accumulate higher levels of debt and sovereign spread would be substantially higher. The impossibility to use inflation to dilute debt makes the fiscal authority more tempted to default. I also compare the baseline model with an economy where the central banker is fully controlled by the fiscal authority to show that the equilibrium levels of debt are reduced, at the cost of higher inflation rates.

Finally I perform a welfare analysis by comparing the baseline economy with the two alternative models described above. The baseline economy displays welfare gains with respect to the fully controlled economy, as the cost of inflation dominates the benefits of higher consumption. However, a fully independent economy shows even stronger welfare gains over the baseline economy, since agents can enjoy lower inflation rates and higher, although temporary, levels of consumption.

The rest of the paper is organized as follows: Section 1.2 will provide a brief review of the literature on sovereign default, inflation and central bank independence; Section 1.3 will provide a brief motivation for this paper; Section 1.4 will describe the theoretical model employed in this paper; Section 1.5 will characterize the theoretical mechanism of the model; Section 1.6 will display the main quantitative results of the model; Section 1.7 will introduce some extension to the baseline model and finally Section 1.8 will conclude the paper.

1.2 Related Literature

In this section I will briefly discuss the literature to which this paper relates to, with the aim of highlighting the main contributions to the existent work.

Firstly, my paper can be related to the vast literature on quantitative models of sovereign default, developed by the seminal work of [4] and continued by papers including [5] and [6], among others. [9] This work incorporates the use of long-term debt, as in [8] and [9]. Within this body of the literature, this paper can be more closely associated with [10], in which the authors develop a New Keynesian Model of sovereign default to study the interaction between monetary policy and default risk and they calibrate their model to Brazil's data. In their model positive correlations between inflation and sovereign spreads are determined by the New-Keynesian nature of their model and the presence of price stickiness. I provide an alternative and complementary explanation for such dynamics. In my work positive levels of inflation and positive correlations between inflation and risk are determined by the equilibrium degrees of central bank control and debt dilution. The possibility to control

[9] [7] provide an extensive survey on the literature of sovereign default.

the central bank is of importance in this context since diluting debt by generating inflation can act as an alternative to default when it is denominated in domestic currency. As in [10], I use global solution methods with the introduction of taste shocks affecting the choice of bonds based on the work of [11] and [12]. In my paper generating inflation to dilute debt leads to nominal devaluations of the domestic currency, as in [13]. In their paper default and devaluations (the twin Ds) are interconnected whenever the exchange rate is floating and optimally controlled by the government; however in their case devaluations are driven by the need to cut real wages in a model with nominal downward wage rigidity, not by debt dilution purposes.

Secondly, this paper is related to the literature that studies inflation and debt dilution. [14] look into the possibility of diluting debt through inflation and how it can reduce a country's exposure to self-fulfilling crises, while at the same time the lack of credibility not to inflate in tranquil times makes debt more costly and default more attractive in the event of a crisis. I also explore the effects of diluting debt by increasing inflation and how this acts as an alternative to default. However, the introduction of the central bank regime can partially reduce the span of debt dilution desired by the sovereign. [15] and [16] also discuss the debt dilution problem when debt is denominated in domestic currency. Other relevant papers discussing government debt and debt dilution are [2], [3] and [17], among others,. The first one analyses the currency composition of sovereign debt in emerging economies and the recent issuance shift from foreign-denominated to domestic-denominated debt. My paper is motivated by the evidence provided by these authors. Unlike [2], my paper does not consider the currency composition of sovereign debt, by focusing on domestic-denominated bonds only, but it includes the option to default, which is of secondary importance in their paper. [17] studies the trade-off between default and debt dilution, showing the existence of a negative correlation between inflation and default risk, which disagrees with the predictions of my paper, which suggests that the correlation is positive. In line with this branch of the literature, [3] study the ”original sin” problem when both foreign and domestic denominated debt is defaultable and inflation is optimally determined by the government.

Thirdly, another important body of the literature associated with this paper is the one discussing the relationship between central bank independence and inflation. Within this framework, some of the most relevant papers include the seminal work of [18], [19] and [20], who argue that central bank independence can succeed in reducing the level of inflation associated with discretionary policy.[10] [21] is one of the first papers to study who appoints the central banker, by constructing a model in which the choice of the conservative central banker is determined by market structure heterogeneity. This paper, although not studying the benefits of a central bank commitment policy, shows that an independent central bank is effectively able to produce a lower level of inflation owing to the elimination of debt dilution incentives. [22] studies how increasing central bank independence can fail to lower the inflation rate in the long-run, as fiscal authorities would use fiscal instruments to decrease current distortions and ultimately leading to an inflationary response by the independent central bank; the author argues that enforcing a strict inflation target would prevent these distortions to happen. My paper does not consider these distortions, as the independent central bank will always follow a strict inflation target policy. Empirical papers analyzing the topic include [23], [24], [25], [26], [27], all studying the correlation between central bank independence and the level inflation and highlighting that such a correlation is negative both for developed and emerging economies. [28] provides a review of the literature on central bank independence and illustrates the difference between *de jure* and *de facto* independence both in emerging and developed economies.

Lastly, and perhaps more importantly, this paper contributes to the rising literature that merges quantitative models of sovereign default and Central Bank Independence. [29] is one of the first papers to discuss the effects of having a separate fiscal and monetary authority in a sovereign default model, although the primary aim of the paper is to study how this distinction affects the desire to accumulate international reserves. My paper, although related to the idea of a central bank in the context of a sovereign default model, differs in the fact that while in [29] there is a central bank which is assumed to be exogenously independent from the sovereign (in the decision to accumulate international reserves), in my paper the sovereign optimally chooses whether the monetary authority

[10] In particular, [20] argues that conservative central bankers reduce the inflationary bias.

is independent or not and hence determines the optimal inflation rate.

To the best of my knowledge, this is the first paper to endogenize the choice of central bank independence in a sovereign default environment, as the monetary autonomy is determined by an explicit decision of the central government, optimally, based on the state of the economy.

The next section will briefly provide some empirical motivation for this paper.

1.3 Empirical Motivation

In this section I present motivating facts concerning government debt, inflation and central bank independence for emerging economies. My sample includes 14 emerging economies, a subset of the countries included in [2], due to the data availability on local currency debt. Following their paper, the set of countries included in the sample are middle-income economies tracked in J.P. Morgan's EMBI time series.[11]

I collect data for average public external debt from the World Development Indicators (WDI) for the period 2000-2020. Public external debt is expressed as a percentage of GDP and it corresponds to public and publicly guaranteed debt comprising long-term external obligations of public debtors, including the national government, Public Corporations, State Owned Enterprises, Development Banks and Other Mixed Enterprises, political subdivisions, autonomous public bodies, and external obligations of private debtors that are guaranteed for repayment by a public entity. Meanwhile, public external debt denominated in local currency is obtained from [30], which spans from 2004 to 2014.

Inflation data is collected from the World Bank for the period 2000-2020 and it reflects the year-on-year percentage changes of the average Consumers Prices Index for the countries in my sample.

Spread levels are collected from the J.P. Morgan's EMBI+ (Emerging Markets Bond Index

[11]Specifically, the sample includes: Argentina, Brazil, Bulgaria, China, Egypt, India, Indonesia, Mexico, Peru, Philippines, Russia, South Africa, Thailand and Turkey.

Plus) and publicly available in the Global Financial Monitor from World Bank for the window 2000-2020. This index is denominated in basis points and it is widely used in the literature as a good proxy of sovereign default risk for emerging economies.[12]

1.3.1 Stylized Facts

I document three main stylized facts about emerging economies.

Fact 1. The share of external debt denominated in local currency has increased in emerging economies.

On average, developing countries have succeeded in reducing their overall level of public external debt[13]. Moreover, papers such as [2] discuss a recent shift in the currency composition of sovereign debt in emerging economies. Figure A.1 shows an average increase in the share of external debt denominated in local currency over the window 2004-2014. With few exceptions, such as Argentina, India and Thailand, this trend is particularly pronounced in other emerging economies. In Latina America, a strong increase of local currency debt issuance can be observed in Brazil and Mexico, who are now mainly issuing debt denominated in their local currency. This result suggests the growing importance of understanding the problems associated with the issuance of debt denominated in domestic currency, as this source of financing is (becoming) dominant in many emerging economies.

Fact 2. In emerging economies inflation is positively correlated with sovereign debt levels and sovereign spreads.

Emerging economies are characterized by a positive unconditional correlation between the inflation rate and the level of public external debt in terms of GDP. The left panel in Figure A.2

[12] Roughly, 100 basis points in the EMBI+ index indicate that the yearly default probability of the analyzed bond is 1%.

[13] Between 2000 and 2020, public external debt reduced to approximately 22.1% of GDP, a 15.51 percentage points decrease.

depicts this correlation for the same sample of emerging economies described above. With the exception of South Africa, displaying a correlation close to -0.3, all the other economies in my sample show a positive relation between inflation and debt. The positive observations range from the highs of Turkey, around 0.9, to the lows of Thailand and Argentina below 0.2. Brazil and Mexico, two countries with high shares of debt denominated in local currency, show correlations around 0.6 and 0.4, respectively.

The right panel in Figure A.2 depicts the unconditional correlation between the inflation rate and spread. Despite the cross-country heterogeneity, on average I can observe strong and positive correlations for most of the countries with the exception of Indonesia. While the correlation is weaker in some cases as in Argentina, Ghana and Egypt, countries such as Russia (close to 0.95), India and Mexico display almost perfect linear correlations.

Both correlations may seem to suggest that emerging economies tend to dilute government debt through higher inflation, particularly in periods in which default risk is higher. In a world in which the central bank is fully independent, i.e. focused on price stabilization only as this is the case for most central banks, inflation should not be correlated with any other economic variables. Viceversa, a fully controlled central bank is expected to internalize how changes in debt and default risk affect consumption, hence a perfect correlation is expected. However the data does not suggest that this is the case, indicating that central bank independence is neither complete nor absent.

Fact 3. De jure independence indicators do not necessarily reflect de facto central bank independence

As already mentioned, *de jure* and *de facto* central bank independence indicate two different objects. As pointed out in [28], *de jure* measures of independence tend to capture legal independence, such as appointment and dismissal of central bank governors; financial independence, i.e. the resources available to conduct operations; objective independence, such as determining the goal of the central bank; or tool independence, i.e. what are the tools available to the central bank and under what circumstances they can be used. On the other side, *de facto* central bank independence indicates the actual, or effective, level of independence that a central bank possesses. In broad terms, this concept states how central bankers operates free from political pressure in the pursuit of their goals[14]. In my paper I will refer to the latter definition of independence.

One of the most popular indexes aimed at capturing *de jure* central bank independence is constructed by [25]. More recently, [27] updated the original Cuckierman index by extending coverage between 1970 and 2012 and including 182 countries. This index ranges in the unit interval, with values close to 0 indicating more controlled central banks, and values close to 1 indicating more independent central banks.

Figure A.3 reports the average *de jure* central bank independence index for the 14 emerging economies of my sample and other 14 developed countries over the period 1970-2012. Red bars represent the average CBI index for developed countries[15] while blue bars represent emerging economies. As it can be seen, there is no evidence that developed economies enjoy higher levels of *de jure* central bank independence with respect to emerging countries. For instance, emerging economies such as Bulgaria, Turkey or Argentina display much higher levels of independence than many developed countries such as Netherlands, France or USA. Therefore, if more independent central banks can achieve lower (and less volatile) levels of inflation, *de jure* central bank independence indicators do not seem to capture *de facto* (or actual) levels of independence.

In the next section I construct a quantitative sovereign default model in which the actual level of central bank independence is endogenous and determined by observable economic fundamentals.

[14]Price stabilization is the primary goal of most central banks in emerging economies. See [28] for reference.

[15]In the sample, the developed countries are: Germany, Austria, Netherlands, Switzerland, France, Italy, Finland, Canada, USA, Great Britain, Australia, Japan, Sweden, Norway.

1.4 The Model

1.4.1 The environment

Time is infinite and discrete, indexed by $t \in 0, 1, 2, ...$, and the economy is populated by private and public agents. The former set is constituted by domestic households, who receive an endowment of tradable goods, pay lump-sum taxes and consume, and by international investors, who purchase domestic government bonds. The latter set is constituted by the monetary authority, which I will refer to as M, and by the fiscal authority, referred as F.

In this model the fiscal authority finances public expenditure through lump-sum taxes collected from households and through issuance of defaultable long-term, domestically denominated debt to international investors. In every period the monetary authority is appointed by the fiscal authority with a given level of independence, determined by the fiscal authority itself, and it determines the optimal level of inflation for the domestic economy.

Households - In every period households receive an endowment of tradable goods y_t, which follows an exogenous stochastic process given by

$$\log(y_t) = \rho_y \log(y_{t-1}) + \sigma_y \varepsilon_t \tag{1.1}$$

where $\rho_y \in [0, 1]$ and $\sigma_y \in \mathbb{R}^+$ denote, respectively, the persistence and the standard deviation of the stochastic process, and $\varepsilon_t \sim N(0, 1)$.

Households are hand-to-mouth and they employ the endowment received y_t to finance private consumption c_t and to pay lump-sum taxes T_t to the fiscal authority. The period-by-period budget constraint is given by:

$$c_t = y_t - t_t \tag{1.2}$$

Preferences are defined over an infinite stream of consumption and inflation:

$$\mathbb{E}_0 \sum_{t=0}^{+\infty} \beta^t \left(u(c_t) - l(\pi_t)\right) \tag{1.3}$$

where $\beta \in (0,1)$ defines the households' subjective discount factor and π_t defines the gross inflation rate at time t [16]. The instantaneous utility of consumption $u(\cdot)$ is differentiable, increasing and concave and the instantaneous (dis)utility of inflation $l(\cdot)$ is differentiable and convex. Following [2] the disutility from inflation captures distortionary costs associated with inflation [17].

Fiscal and monetary authorities - The fiscal authority (F) collects lump-sum taxes from households and incurs in a fixed amount of public spending $g \in \mathbb{R}^+$ in every period [18]. In addition I assume that the fiscal authority can issue nominal non-contingent bonds denominated in units of the domestic currency to international investors, which are described later.

In every period, F can either repay its debt, in which case F is in state of repayment (R), or default on its debt, being in state of default (D). In states of default, F is excluded from international financial markets and its budget constraint is given by:

$$t_t = g \tag{1.4}$$

Hence, in state D the budget is balanced and the goods market clearing condition for the tradable good is:

$$c_t = y_t - g \tag{1.5}$$

In state R the fiscal authority can issue bonds. As in [8], the bond is a perpetuity specifying a (nominal) price q_t and a quantity N_t such that the government receives $q_t N_t$ units of domestic currency in period t. The following period, a fraction $\delta \in (0,1]$ of debt matures, calling a unit

[16] The current-period gross inflation rate is defined as $\pi_t = \frac{P_t}{P_{t-1}}$, where P_t denotes the time t price level.

[17] Distortions from inflation can be rationalized in models with money in the utility function and models with credit and cash goods, as in [2].

[18] Evidence from emerging economies indicates that government spending tends to be sticky, justifying the assumption of constant spending. See [31] for references

payment of $r + \delta$, where $r \in [0,1]$ is the international discount rate; the next-period level of debt is given by unmatured debt $(1-\delta)B_t$, where $B_t \in \mathbb{R}^+$ is the outstanding nominal level of debt at time t, and new issuance N_t. Notice that maturity increases as δ decreases; the case of $\delta = 1$ corresponds to one-period bonds, while the case of $\delta = 0$ corresponds to consols [19]. The fiscal authority's budget constraint is expressed in real terms and it is given by:

$$t_t = g - q_t\left(b_{t+1} - (1-\delta)\frac{b_t}{\pi_t}\right) + (r+\delta)\frac{b_t}{\pi_t} \tag{1.6}$$

where b_t is the outstanding level of debt in real terms and b_{t+1} is the level of real debt carried over to the next period [20]. Therefore, in state R, the goods market clearing condition of the tradable good is:

$$c_t = y_t - g + q_t\left(b_{t+1} - (1-\delta)\frac{b_t}{\pi_t}\right) - (r+\delta)\frac{b_t}{\pi_t} \tag{1.7}$$

When the fiscal authority defaults on its debt, F is excluded from financial markets and it can reenter with an exogenous probability $\theta \in (0,1)$ and with no outstanding debt, i.e. $b_t = 0$. Following [6] and [9], I assume that the fiscal authority suffers from direct disutility of default $\phi(y) \in \mathbb{R}$, which is increasing in income. This assumption is intended to capture the fact that, other things equal, F prefers defaulting in bad times rather than in good times.

The fiscal authority, in addition to the choices of debt and default, appoints a new central banker in every period, who runs the monetary authority. The central banker lives for one period and is replaced by a newly appointed central banker thereafter. There is a continuum of central bankers in the unit interval, i.e. $i \in [0,1]$, each having a different utility function that depends on c_t, π_t and i. For a given level of c_t and π_t, i_t can be thought of as the degree of independence of the central banker: the higher is i_t, the more independent is the central banker. The preferences of the central banker are represented by the following objective function:

[19] The law of motion of debt (in nominal terms) is $B_{t+1} = (1-\delta)B_t + N_t$.

[20] $b_{t+1} \equiv \frac{B_{t+1}}{P_t}$ and $b_t \equiv \frac{B_t}{P_{t-1}}$.

$$(1-i)u(c_t) - l(\pi_t) \tag{1.8}$$

As it can be seen, higher levels of independence imply that the central banker values consumption less. In the limiting case that $i = 1$ the central banker is fully independent and it will seek to minimize inflation distortions only [21].

For the fiscal authority appointing less independent central bankers is costly (e.g. reputation costs associated with having less credible institutions) and the cost is represented by the function $z(y,i) : \mathbb{R}^+ \times [0,1] \to \mathbb{R}^+$, which I assume to be increasing in the level of the endowment and decreasing in the independence level, reflecting the fact that appointing a less independent central banker is more costly for the fiscal authority, and such cost is higher if it occurs in good times. In addition, I assume that $z(y,1) = 0$ for each y, i.e. the fiscal authority does not bear any reputational cost in appointing the most independent central banker.

Given the state of the world D_t, the fiscal authority maximizes the following objective function:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{+\infty} \beta_F^t \left(u(c_t) - l(\pi_t) - D_t \phi(y_t) - z(y_t, i_t) \right) \right\} \tag{1.9}$$

where $\beta_F \in (0,1)$ denotes the subjective discount factor of the fiscal authority, which I assume to be lower than the households', i.e. $\beta_F < \beta$, denoting a higher degree of impatience than international investors, which I describe later[22]. Notice that the disutility of default appears only whenever $D_t = 1$, i.e. only states of default.

Nominal exchange rate and international investors - Debt is denominated in units of the domestic currency, hence I need to define a measure of nominal exchange rate that allows foreign investors to convert domestic currency into foreign currency. I define the nominal exchange rate e_t as the price of one unit of foreign currency in terms of local currency. Given this definition, a nominal

[21] This assumption seems to be consistent with the fact that, formally, most independent central banks operate according to a single mandate only, i.e. price stabilization.

[22] This assumption ensures that this economy is a net borrower from the rest of the world.

depreciation episode corresponds to an increase in e_t. I also assume that the law of one price holds i.e. $P_t = e_t P_t^*$, where P_t^* is the price level of the rest of the world. I assume that $P_t^* = 1$ [23], which implies that changes to the nominal exchange rate are entirely determined by changes in domestic fundamentals. International investors are deep pocketed, risk-neutral and discount the future at a rate $\beta = \frac{1}{1+r}$. They purchase nominal sovereign bonds denominated in units of domestic currency from the fiscal authority. The bond price is such that, in expected value, international investors break-even, i.e. they are compensated for any expected loss from default D_{t+1} and from expected nominal exchange rate devaluation $\frac{e_{t+1}}{e_t}$:

$$q_t = \beta \mathbb{E}_t \left((1 - D_{t+1}) \frac{e_t}{e_{t+1}} (r + \delta + (1 - \delta) q_{t+1}) \right) \tag{1.10}$$

The nominal price of government bonds is decreasing in (expected) default risk and in (expected) nominal exchange rate devaluations.

Exploiting the law of one price allows us to rewrite the bond price schedule as:

$$q_t = \beta \mathbb{E}_t \left(\frac{1 - D_{t+1}}{\pi_{t+1}} (r + \delta + (1 - \delta) q_{t+1}) \right) \tag{1.11}$$

As it can be observed, the price of domestic government bonds is negatively affected by high levels of expected domestic inflation, which is equivalent to expected nominal exchange rate devaluations.

Timing - The timing of actions of this economy is described as follow:

1. The income process y_t realizes and the aggregate state of the economy is given by (y_t, b_t).
2. The fiscal authority chooses whether to default or not.
    - If default occurs, $D_t = 1$, F is excluded from financial markets and the central banker $i(y_t)$ is appointed by the fiscal authority;

[23] Although not necessary, this assumption allows us to focus on domestic factors affecting the nominal exchange rate. Relaxing this assumption would have no effect on the analysis.

- If repayment occurs, $D_t = 0$, F chooses new debt b_{t+1}, given the state (y_t, b_t) and taking the bond price schedule $q(y_t, b_{t+1})$ as given, and the central banker $i(y_t, b_t)$ is appointed by the fiscal authority;

3. The monetary authority is run by the central banker of type $i \in [0, 1]$ appointed by the fiscal authority.
   - If default occurs, $D_t = 1$, M chooses the inflation rate π_t given the state (y_t);
   - If repayment occurs, $D_t = 0$, M chooses the inflation rate π_t given the state (y_t, b_t, b_{t+1});
4. Old debt b_t is paid, new debt b_{t+1} is issued and households consume c_t.

1.4.2 Recursive problem

In this economy the only agents making strategic decisions are the fiscal and the monetary authorities, as households consume their after-tax endowment and international investors supply bonds inelastically at their given price. The environment can be understood as a sequential game in which the fiscal authority moves first, by choosing default, debt and degree of independence, and internalizing M's optimal inflation policy, and the monetary authority moves second after observing the state (y, b, b') and given the central banker's type i.[24]. I start by looking at the recursive problem of the monetary authority.

Monetary authority - Let $V_j^M(\cdot)$ denote the monetary authority's value function in state $j = \{D, R\}$ where, as already described, D denotes the state of default and R the state of repayment. In state $j = D$ the monetary authority of type i takes as given the state y and M's value function is given by:

$$V_{i,D}^M(y) = \max_{\pi} \; (1 - i)u(c) - l(\pi) \tag{1.12}$$

subject to the resource constraint under default, which I repeat for convenience:

[24] I denote current period variables without time index and next period variables with $'$.

$$c = y - g \tag{1.13}$$

The solution to (2.22) yields a best response for inflation in state D, which is trivially given by $\hat{\pi}^M_{i,D}(y) = \arg\max_\pi \; (1-i)u(c) - l(\pi)$.

In state $j = R$ type i's monetary authority takes as given the state (y, b, b'), and M's value function is:

$$V^M_R(y, b, b', i) = \max_\pi \; (1-i)u(c) - l(\pi) \tag{1.14}$$

subject to the resource constraint under repayment:

$$c = y - g + q(y, b')\left(b' - (1-\delta)\frac{b}{\pi}\right) - (r+\delta)\frac{b}{\pi} \tag{1.15}$$

A best response for inflation in state R is given by $\hat{\pi}^M_{i,R}(y, b, b')$ as the solution to (2.24). Given the sequential nature of the problem, the monetary authority does not internalize F's optimal policies.

Fiscal authority - The fiscal authority moves first and F internalizes M's best inflation response $\hat{\pi}_j$ for $j = \{D, R\}$. Let $V^F(\cdot)$ be the value function of the fiscal authority that faces the state (y, b) and let $V^F_j(\cdot)$ be the fiscal authority's value function in state j. The function $V^F(\cdot)$ satisfies the functional equation:

$$V^F(y, b) = \max_{D \in \{0,1\}} \; \left\{(D)V^F_D(y) + (1-D)V^F_R(y, b)\right\} \tag{1.16}$$

where F's value function in state D is represented by:

$$V^F_D(y) = \max_{i \in [0,1]} \; u(c) - l(\pi) - \phi(y) - z(y, i) + \beta_F \mathbb{E}_{y'|y}\left[\theta V^F(y', 0) + (1-\theta)V^F_D(y')\right] \tag{1.17}$$

subject to (1.13) and:

$$\pi = \hat{\pi}^M_{i,D}(y) \tag{1.18}$$

and F's value function in state R can be seen as:

$$V^F_R(y,b) = \max_{i\in[0,1],b'} \quad u(c) - l(\pi) - z(y,i) + \beta_F \mathbb{E}_{y'|y}\left[V^F(y',b')\right] \tag{1.19}$$

subject to (1.15) and:

$$\pi = \hat{\pi}^M_{i,R}(y,b,b') \tag{1.20}$$

The solution to (2.13) yields decision rules for default, $\hat{D}(y,b)$, debt issuance $\hat{b}(y,b)$, inflation $\hat{\pi}(y,b)$ and degree of central bank independence $\hat{\imath}(y,b)$. The decision rule for default equals 1 if the fiscal authority defaults and 0 otherwise. Notice that, given the sequential timing of actions of the model, the optimal inflation rate is given by M's best inflation response taking as given F's optimal first moves.

Bond price schedule - International investors price domestic bonds with the price schedule:

$$q(y,b') = \beta \mathbb{E}_{y'|y}\left[\frac{1-\hat{D}(y',b')}{\hat{\pi}(y',b')}(r+\delta+(1-\delta)q(y',b''))\right] \tag{1.21}$$

where $b'' = \hat{b}(y',b')$ is next period's bonds policy function.

I can now define the Markov perfect equilibrium of this economy.

Definition 1 (Markov Perfect Equilibrium) *A Markov perfect equilibrium for this economy is defined as:*

(i) a set of value functions $V^M_{i,R}(y,b,b')$, $V^M_{i,D}(y)$, $V^F(y,b)$, $V^F_R(y,b)$, $V^F_D(y)$;

(ii) associated policy functions for default $\hat{D}(y,b)$, *borrowing* $\hat{b}(y,b)$, *degree of central bank independence* $\hat{\imath}(y,b)$, *inflation in default* $\hat{\pi}_D(y)$, *inflation in repayment* $\hat{\pi}_R(y,b)$, *and consumption* $\hat{c}(y,b)$;

(iii) a bond price schedule $\hat{q}(y, b')$*;*

such that:

(a) Given the bond price schedule, the central banker's type i *and the state* y*, the reaction function* $\hat{\pi}_{i,D}^{M}(y)$ *solves the optimization problem* (2.22)*;*

(b) Given the bond price schedule, the central banker's type i *and the state* (y, b, b')*, the reaction function* $\hat{\pi}_{i,R}^{M}(y, b, b')$ *solves the optimization problem* (2.24)*;*

(c) Given the bond price schedule and the monetary authority's reaction functions, the policy functions $\{\hat{D}(y, b), \hat{b}(y, b), \hat{\imath}(y, b)\}$ *solve the optimization problems* (2.13)*,* (2.14)*,* (2.18)*;*

(d) Given the bond price schedule, M's reaction functions and F's policy functions, the policy functions for inflation are $\hat{\pi}_D(y)$ *and* $\hat{\pi}_R(y, b)$*;*

(e) Given the bond price schedule and the other policy functions, $\hat{c}(y, b)$ *satisfies the resource constraint;*

(f) The bond price schedule satisfies (2.28)*, where* $b'' = \hat{b}(y', b')$*.*

In the next section I will dig deeply into the mechanism of our model and explain the driving forces of the authorities' decisions.

1.5 Mechanism

I now analyze the problem faced by the monetary authority (M) and the fiscal authority (F), which is crucial to understand the quantitative results. In the model F moves first, anticipating M's best response, and M responds after having observed F's policies. The dynamic of the interaction between the two authorities depends on the state *D*, i.e. whether the fiscal authority has access to financial markets or not.

Default state - In state of default $D = 1$ the monetary authority chooses the best inflation response $\hat{\pi}_{i,M}^{D}(y)$, which is the solution of (2.22):

$$l'(\pi) = 0 \tag{1.22}$$

This condition states that, at the optimum, M will choose a level of inflation such that the marginal disutility of inflation is nil. As described above, the function $l(\pi)$ depends only on π, which leads to the following:

Proposition 1 *Given the state $D = 1$ and given the state y, the best inflation response function is not affected by the degree of central bank independence and by the realization of the stochastic process y.*

In addition, if I assume that the disutility function is convex and symmetric around an ”inflation target”, (1.22) implies that that the optimal inflation response of the monetary authority is given by such inflation target. In other words, this economy does not display any inflation rate other than the inflation target.

On the other hand, given the best response of the monetary authority, the fiscal authority’s policy is the solution of (2.14):

$$\frac{\partial z}{\partial i} = 0 \tag{1.23}$$

Notice that the function $z(\cdot)$ is decreasing in the degree of central bank independence, hence I have the following:

Proposition 2 *Given the state $D = 1$ and for each realization of the productivity y, the optimal degree of central bank independence determined by the fiscal authority is 1.*

Since in states of default the fiscal authority is excluded from financial markets, the level of consumption is not affected by inflation dynamics, thus eliminating any incentive to inflate the economy to boost consumption. Hence, F has no incentives to appoint a non-independent central banker.

Repayment state - In state of repayment M chooses the best inflation response $\hat{\pi}^R_{i,M}(y, b, b')$ as the solution of (2.24):

$$l'(\pi) = (1 - i)u'(c)(r + \delta + (1 - \delta)q(y, b'))\frac{b}{\pi^2} \tag{1.24}$$

where the left hand side and the right hand side represent, respectively, the marginal disutility and the marginal utility of one extra unit of gross inflation. While increasing the inflation choice makes agent incurring into more disutility, it also provides the benefit of partially diluting the existing stock of debt b, increasing the utility derived from consuming more in the current period. Since the mandate of the monetary authority is single, i.e. stabilizing inflation, an independent central banker does not perceive the benefit (utility) of increasing consumption through inflation, while higher levels of non-independence increase the marginal utility of inflation.

Furthermore, I can characterize the best response of the monetary authority for changes of the underlying economic fundamentals. For simplicity I look at the case of risk-neutral agents, however my results are robust in the case of risk-averse agents in the quantitative model.

Proposition 3 *Assume that the function $u(c)$ is such that, for each c, $u'(c) = 1$ and $u''(c) = 0$. Then, the monetary authority's best inflation response is increasing in b and y and decreasing in i and b'.*

Proof. Appendix. ■

Intuitively, inflation is lower the higher the degree of independence of the central banker because a more independent central banker seeks to stabilize inflation and does not perceive the benefits of increasing inflation in terms of units of consumption. Inflation is also increasing in the beginning-of-the-period stock of debt because the monetary authority can reduce the burden of repayment by diluting the real value of bonds. The behavior of the best inflation response is less straightforward in the other two cases and it relies on the nature of long-debt contracts. In this scenario higher levels of inflation not only reduce the burden of repayment, but they also increase the amount of debt to be refinanced by F at the current price $q(y, b')$. Given that the price function is increasing (decreasing) in the level of the endowment y (next-period bonds b'), higher levels of inflation imply higher debt issuance at a more (less) favorable price. Therefore the monetary authority optimally raises inflation for higher (lower) levels of the endowment (next-period bonds).

On the other side, the fiscal authority internalizes the best response of the monetary authority and F optimally chooses the degree of central bank independence i and the optimal next-period level of bonds, conditional on not defaulting in the current period, as the solution of (2.18). At the (interior) optimum, the degree of central bank independence is represented by:

$$\underbrace{l'(\pi) + \frac{\frac{\partial z}{\partial i}}{\frac{\partial \hat{\pi}_R}{\partial i}}}_{\text{Marginal cost of inflation}} = \underbrace{u'(c)(r + \delta + (1-\delta)q)\frac{b}{\pi^2}}_{\text{Marginal benefit of inflation}} \tag{1.25}$$

where the left hand side represents the marginal cost and the right hand side is the marginal benefit of inflation for the fiscal authority. Notice that the term $\frac{\frac{\partial z}{\partial i}}{\frac{\partial \hat{\pi}_R}{\partial i}}$ is always non-negative, since higher independence increases F's utility and reduces the best inflation response of the central banker. The combination of these two effects make the marginal cost of inflation of the fiscal authority higher than the marginal cost of inflation of the monetary authority. This implies that, assuming that reputational costs are positive, the fiscal authority would optimally choose a lower level of inflation than a fully controlled monetary authority. This leads me to the following:

Proposition 4 *Assuming that $z(y, i) = 0$ for all y and for all i, the optimal inflation rate of the economy solves:*

$$u'(c)(r + \delta + (1-\delta)q(y, b'))\frac{b}{\pi^2} = l'(\pi) \tag{1.26}$$

Moreover, the monetary authority is fully controlled by the fiscal authority, i.e. $i = 0$.

Proof. Appendix. ■

This result states that, absent controlling cost, this dual authorities economy boils down to a single authority economy in which F makes both borrowing and inflation decisions.

The fiscal authority's borrowing decision is represented as the solution to the following equation:

$$\underbrace{\overbrace{u'(c)\left(\frac{\partial q}{\partial b'}\left(b'-(1-\delta)\frac{b}{\pi}\right)+q\right)}^{\text{Marginal benefit of issuing debt}}+\overbrace{\frac{\partial \hat{\pi}_R}{\partial b'}\frac{\partial z/\partial i}{\partial \hat{\pi}_R/\partial i}}^{\text{Marginal benefit distortion}}}_{\text{Net marginal benefit of issuing debt}}=\cdots$$
$$=\underbrace{\overbrace{\beta\mathbb{E}_{y'|y}\left[(1-D')u'(c')\frac{r+\delta+(1-\delta)q'}{\pi'}\right]}^{\text{Marginal cost of issuing debt}}-\overbrace{\beta_F\mathbb{E}_{y'|y}\left[(1-D')\frac{\partial \hat{\pi}_R'}{\partial b'}\frac{\partial z'/\partial i'}{\partial \hat{\pi}_R'/\partial i'}\right]}^{\text{Marginal cost distortion}}}_{\text{Net marginal cost of issuing debt}} \tag{1.27}$$

where the left hand side represents the net marginal benefit of one extra unit of borrowing and the right hand side represents the net marginal cost of one extra unit of borrowing. I can decompose each side of the equation in two parts to better understand the mechanism driving borrowing decisions. The marginal benefit of issuing debt and the marginal cost of issuing debt are expressed in terms of current units of consumption and they are standard in the sovereign default literature. Notice that higher expected inflation π' affects borrowing decisions by reducing the expected future cost of repayment.

A novelty of this paper is presented by the borrowing distortions, which I call, respectively, marginal benefit distortion and marginal cost distortion. The fiscal authority internalizes the best inflation response of the monetary authority $\hat{\pi}_M^R$ and F knows that its borrowing decision will affect M's best response. The marginal benefit distortion reduces the marginal benefit of issuing one extra unit of bonds, because in doing so, the fiscal authority internalizes the fact that the monetary authority will optimally respond by reducing the inflation rate, thus reducing current period consumption; the presence of a dual regime acts as a discipline effect and leads to *underborrowing*. The marginal cost distortion reduces the marginal cost of borrowing: the fiscal authority anticipates that, by increasing borrowing today, the monetary authority will optimally decide to increase future inflation, which will reduce F's burden of repayment; in this situation the presence of a dual regime leads to *overborrowing*. The two distortions operate in different directions, hence the overall effect is unclear and it will depend on the functional forms and the relative calibration of the model.

Notice that, whenever $i = 0$ or $i = 1$, the following holds:

Proposition 5 *For* $i = 0$ *and* $i = 1$ *the borrowing decision is undistorted and represented as:*

$$u'(c)\left(\frac{\partial q}{\partial b'}\left(b' - (1-\delta)\frac{b}{\pi}\right) + q\right) = \beta_F \mathbb{E}_{y'|y}\left[(1-D')u'(c')\frac{r + \delta + (1-\delta)q'}{\pi'}\right]$$

Proof. Appendix. ∎

The presence of a dual regime distorts the optimal borrowing decision of the fiscal authority, unless the monetary authority is either fully independent or fully controlled by the fiscal authority.

1.6 Quantitative Results

1.6.1 Functional forms

Households and the fiscal authority value consumption with a constant relative risk aversion instantaneous utility function:

$$u(c) = \frac{c^{1-\sigma} - 1}{1-\sigma} \tag{1.28}$$

where $\sigma \in \mathbb{R}^{++} \setminus \{1\}$ and $u(c) = \log(c)$ if $\sigma = 1$.

The (dis)utility associated to inflation is weighted with the loss function:

$$l(\pi) = \frac{\chi}{2}(\pi - \bar{\pi})^2 \tag{1.29}$$

with $\chi \in \mathbb{R}^{+}$ and $\bar{\pi} \in \mathbb{R}^{++}$ being, respectively, a scale parameter governing the magnitude of loss associated with inflation distortions and the inflation target value. Notice that higher values of χ are associated with higher disutility attached to inflation distortions, i.e. lower inflation tolerance, while lower values of χ are associated with higher inflation tolerance. As in [2], this functional form is symmetric around the inflation target, implying that households dislike both low and high values of inflation.

Following [32], the utility cost of defaulting is given by $d(y) = \alpha_0 + \alpha_1 \log(y)$, with $\alpha_0, \alpha_1 \in \mathbb{R}^+$. The presence of two parameters better allows me to capture the levels of debt and spread observed in the data.

The function $z(y, i)$ aims at capturing the utility cost associated with appointing non-independent central bankers. I assume that this function takes the form $z(y, i) = z_0 y(1 - i)$, where $z_0 \in \mathbb{R}^+$ is a parameter that allows me to capture the disutility associated to appointing non-independent central bankers for given levels of (y, i).

1.6.2 Parameters

I solve the model numerically in order to evaluate its quantitative predictions concerning the level of foreign debt denominated in local currency, sovereign spread, inflation and the correlations among these macroeconomic variables. The model is calibrated using data for Brazil at annual frequency from 2000 to 2020[25], an economy that displays a sufficiently high share of debt denominated in local currency, making debt dilution and inflation a meaningful problem. I have divided the parameter set in two: the first set is constituted by parameters that are either from the literature or calibrated from Brazil's data, while the second set of parameters is constructed to match key aspects of the data.

Calibrated parameters - The risk aversion parameter σ takes the value of 3 and it is standard in the sovereign default literature. The inflation disutility parameter χ is normalized to 1. The volatility and persistence of the exogenous stochastic process y are calibrated to replicate the stochastic process of the cyclical component of Brazil's GDP. From our estimation we obtain $\rho_y = 0.6$ and $\sigma_y = 0.02$. The investors' discount rate $r = 0.011$ is set to match the average real interest rate for US T-Bills from 1980 to 2017. The reentry probability $\theta = 0.2$ is calibrated to match Brazil's average duration

[25] I exclude periods preceding 2000, since Brazil experienced a period of hyperinflation till 1994-1995 and since I do not have data about debt in local currency for earlier years.

of exclusion from financial markets, which is approximately 5 years. The public expenditure share g is set to match the average level of the ratio spending/GDP in Brazil from 2000 to 2020, which is approximately 38%. The average debt maturity of Brazil's debt is approximately 7 years, yielding a value of 0.1422 for the coupon decay rate δ. The inflation target parameter $\bar{\pi}$ is set to match the average official inflation target declared by the Central Bank of Brazil over the period 2000-2020, which is approximately 4.5%.

Parameters set by simulations - Four parameters are calibrated by simulations: the fiscal authority's discount factor β_F, the default disutility parameters α_0 and α_1 and the disutility cost of non-independence z_0. Given the numerical challenges related to the solution of sovereign default models, these four parameters are chosen to match four targets in the data: (i) an average inflation rate of 6.2%; (ii) an average spread level close to 412 basis points[26]; (iii) an average debt to GDP ratio[27] around 9.8%; (iii) an average spread-inflation correlation around 0.57.

Table B.1 summarizes the parameter values.

1.6.3 Model vs Data

I report the main statistics from the data and the simulations in Table B.2. The model's statistics are computed by simulating the model for 50,000 periods, starting from a nil level of initial debt and with a median endowment realization. I then drop the first 1,000 periods in order to get rid of the influence of the initial conditions and I consider only the statistics in repayment states[28], as no default occured in Brazil in my dataset window.

As already mentioned, the first set of moments matches its data counterpart. The model seems to be matching quite well the targeted moments, although it undershoots the long run debt/GDP ratio

[26]Notice that the EMBI+ index does not allow me to disentangle between the spread level associated to domestic and foreign denominated debt.

[27]Given the difficulty related to data availability regarding the denomination of government debt, I assume that debt is denominated in local currency units. While such assumption seems to be unrealistic for early periods of my dataset, it reflects the currency composition of recent years.

[28]Following [10] I also exclude the first 5 periods after reentry from a default episode.

by 0.6 percentage points. On the one side, the model seems to be good at matching other moments of the data such as the standard deviation of spread, the consumption-output correlation and the debt-output correlation. On the other side it appears that the model overestimates the inflation-debt correlation, and the spread-GDP correlation. I believe that other features could be included in order to better match some of the untargeted moments, as the model only considers inflation as a debt dilution instrument and debt as a way to smooth consumption of the single tradable good.

1.6.4 Central bank independence

The novelty of my model is the determination of an implicit indicator of *de facto* central bank independence level. As most central banks formally follows an inflation target, which is also the case of the Central Bank of Brazil, I have modeled an independent central banker as an agent that weighs inflation only in its utility function. As a central banker is more and more controlled, it will weigh consumption more and more in its utility function, until its preference and the preferences of the fiscal authority are identical when $i = 0$.

According to my model, if central bankers were fully independent, I should not observe any correlation between debt and spread with inflation, as the central banker would seek to stabilize inflation independently from any other economic consideration. Conversely, if central bankers were fully controlled by the fiscal authority, I would expect to see perfect correlations between inflation and economic fundamentals. Therefore, in my model *de facto* central bank independence is a shadow indicator that allows me to reconcile what I observe in the data with my theoretical framework.

Table B.3 reports the main statistics from my simulations. The average level of *de facto* central bank independence implied by Brazil's data from 2000 to 2018 is 92%, with a standard deviation of roughly 6%. In the period 2000-2020 I observe in the data an average level of inflation close to 6.2%, which seems to be close with the official target set by the Central Bank of Brazil of 4.5%. I should be expecting a more controlled central bank to deviate more from such target, while I should be expecting a more independent central bank to remain closer. In addition I observe in the data a correlation between spread and inflation of 0.57 and a correlation between inflation and debt of 0.47 (0.71 in the model). In a fully independent environment I would expect both correlations to be close to 0, while in a fully controlled environment I would expect them to be close to 1.

From the model I can also generate the unconditional correlations between independence and other variables of interest. Not surprisingly, I observe large and negative correlations with inflation, as more independent central banks implement stricter inflation policies, and with debt. Independence seems to be procyclical, as pointed out by the correlation with output. Finally I also observe a large negative correlation with the level of spread, implying that sovereign default risk reduces the level of central bank independence.

1.6.5 Impulse response functions

I analyze the dynamic response of the main variables of interest to endowment shocks y. The impulse response functions (IRFs) are constructed by simulating a panel of 100,000 units for 175 periods. For the first 150 periods the shocks follow their underlying Markov chain in such a way that the distribution converges to its ergodic mean. In period 151, which I normalize to 1 in the model, I introduce a 1 standard deviation shock to the endowment realization of y for all the units of the panel. From period 152 onward, shocks resume their Markov processes. The IRFs are computed by averaging the panel units over time.

In Figure A.4 I report the results of our IRFs for output, i.e. the endowment process y, debt/GDP, consumption, spread, inflation and the level of *de facto* central bank independence. For each variable I also report its ergodic mean, depicted as a red line. My panel restricts the analysis to realizations in which the fiscal authority does not default.

The negative realization of the stochastic process leads to an increase in sovereign default risk of more than 300 basis points, which quickly vanishes over time. In turns, this makes the fiscal authority more prone to absorb such shock both through an increase in the debt-to-GDP ration, which raises by roughly 1.5 percentage points, and by a reduction in the central bank independence rate, which falls to 88% from a starting value around 92%. This reduction in independence allows the fiscal authority to increase the inflation rate by roughly 1.2 percentage points. The negative output shock and the increased cost of debt service produces an even stronger decline in consumption, which falls by 6% relative to the average level.

It is worth noticing that, while the output decline and the spread increase converge to their ergodic averages in around 5-7 years, the response of debt-to-GDP, independence and inflation is more persistent. For these variables mean reversion occurs in about 10-11 years and this slow moving effect takes place owing to the nature of government bonds, which are long-period.

This IRFs analysis shows how negative output shocks can threaten *de facto* central bank independence through both the increase in default risk and through the increase of indebtness and how this generates higher inflation rates in the economy for a prolonged period of time.

1.6.6 Counterfactual analysis

In this section I construct a counterfactual analysis by comparing the results of the baseline model, with the results of two alternative economies: one in which the fiscal authority cannot control the monetary policy at all[29] and one in which the fiscal authority always controls the central bank[30]. Table B.4 reports the results of my simulations.

In the "Full Independence" model I observe a substantial increase in the equilibrium debt/GDP ratio from 9.2% to 14.7%, and a clear increase in risk, with spread growing from 417 to 638 basis points. The inflation rate drops from 6.5% to 4.5% as a result of full independence: the central banker does not perceive utility from consumption and thus it aims at minimizes the losses associated to inflation, leading to the monetary authority attaining the objective of a 4.5% inflation rate. The inflation rate is stable at the target, hence its variance is nil. As expected, all real variables are

[29]We assume that the function $z(i, y)$ is large enough that, in equilibrium, F optimally chooses $i = 1$.
[30]Here I assume that $z(i, y) = 0$ for all y and for all i.

uncorrelated with the inflation rate whenever the central banker is fully independent. All other statistics remain largely unaffected.

Intuitively, the lack of inability of controlling the monetary authority not only eliminates the distortions associated with the cost of control, as outlined in Section **??**, but it also eliminates the hedging benefit of diluting debt. By looking at inflation as an additional (partial) default technology, the removal of this option allows the fiscal authority to sustain higher levels of debt, at the cost of a higher risk of outright default.

In the ”Full Control” model the debt/GDP ratio is reduced to 5.6%, at the price of a substantially higher inflation rate, around 13.3%. The level of sovereign risk remains quite unaffected with levels around 455 basis points, although its standard deviation increases to almost 700 basis points. As pointed out in [14] lower inflation disutility can lead to higher inflation without reducing default risk, which seems to be the case in my model. As expected, in this alternative model the inflation-debt correlation is close to 1, since any change in debt leads to changes in the inflation rate caused by debt dilution purposes.

This alternative model shows higher levels of inflation without gains from risk reduction. The welfare comparison of these three models is analyzed in more detail later.

1.6.7 Event analysis

I perform an event analysis and I compare the performance of my model with the Brazilian recession that started in 2015. Figure A.5 reports the results of my event analysis. Data is annual terms for the period 2013-2019.

For the event analysis I feed in a path of endowment shocks such that the time path of output in the model replicates the one in the data. I fix the initial level of debt to the 2012 debt/GDP level observed in the data and I then compare the predictions of the model for inflation, debt/GDP, consumption, spread and I also computed the implied de facto central bank independence level.

The red line with squares in Figure A.5 represents the data, while the blue line with dot represents the model predictions. In 2013 the Brazilian GDP was standing around 5% points above trend and by the end of 2016 output fell by almost 9 percentage points to around -4% below trend. Brazil succeeded in recovering to par levels only in 2019. During this time window the debt to GDP ratio increased from, roughly, 5.5% to values close to 10%. At the same time Brazil experienced a sharp, but limited in timed, increase in the inflation rate, which had jumped from around 6% in 2013 to 9% in 2015. By 2017 the inflation rate fell to values below but close to 4%. The spread level increased as well from around 200 basis points in 2013 to approximately 400 basis points in 2016, followed by a symmetric decline which brought back spread to values close to 200 basis points in 2019. In the data I also observe a decline in the consumption level, from 5% above trend in 2013-2014 to around -3% in in 2016, and slow recovery to before-recession levels in 2019 only.

The model seems to do a good job in replicating the pattern of the debt to GDP level and the behavior of consumption. In the model the major part of the increase in debt takes place between 2014 and 2016, with stable values afterwards, in line with the data. I also reproduce the dynamic of the increase in sovereign spread associated with the recession, even though the model greatly overestimates the increase in absolute terms. In the model I succeed in matching the level of spreads for the period 2013-2015, but I observe a substantially higher increase in 2016, with levels close to 1000 basis points. In the model such increase vanishes quickly and by 2019 the model prediction is close to the data counterpart. The model appears to capture the high levels of inflation of the Brazilian economy. Although in the model the increase is lagged by 2-3 years, the model does a good job in displaying an increase of inflation to levels close to 9%. The model allows me to observe the change in the *de facto* central bank independence rate during the recession. At the beginning of the event window debt and inflation are low, allowing the fiscal authority to leave the central bank independent. The substantial increase in debt and spread lead to a rapid deterioration of the independence level to values close to 85%, with an associated increase in the inflation rate to around 9%.

I also perform a counterfactual analysis of the 2015 recession by comparing the baseline model with two alternative models: (i) a model in which the monetary authority is 100% independent from the fiscal authority and (ii) a model in which the fiscal authority has 100% control over the monetary authority. I report the results in Figure A.6. The black line with crosses represents the baseline model, the red line with empty circles represents Model (i) and the blue line with filled circles represents Model (ii). I feed in the same endowment shocks in all three model and we start the event with the 2012 debt-to-GDP ratio observed in the data.

All three models seems to be similar in terms of behavior of consumption over the entire event window and, as expected, the three models differ in terms of all the other analyzed variables. Model (i) portrays a much stronger increase in the debt-to-GDP ratio with respect to the baseline model and with respect to Model (ii). At the same time the level of spread of Model (ii) is substantially higher than the other models. This is due to the inability of the fiscal authority to control the monetary authority and reduce default risk. Regarding the behavior of the inflation rate for the three different models, while the baseline model shows an increase of the inflation rate associated with the increase in debt and risk, the inflation rate of Model (ii) seems to be much higher and less correlated with the increase in sovereign spreads. Overall the two alternative models are worse than the baseline economy at matching the 2015 Brazilian recession.

This counterfactual analysis highlights the importance of having two authorities with intermediate levels of *de facto* central bank independence.

1.6.8 Welfare Analysis

In this section I study how having a fiscal authority choosing a submaximum level of *de facto* central bank independence affects welfare. In order to explore that, I compare the fully controlled model, as explained above, with the baseline economy and the fully independence model.

To study the welfare gains of having different degrees of central bank independence I follow [29] and proceed as follows. Firstly, I start with a draw from the ergodic distribution of the endowment y and no debt; secondly, I simulate the series of endowment $\{y\}_{t=1}^{T}$ for T =

1000; thirdly, I compute the consumption, inflation and independence paths for all the economies $\{(c_t^{Contr}, c_t^{Base}, c_t^{Indep}, \pi_t^{Contr}, \pi_t^{Base}, \pi_t^{Indep}\}_{t=1}^{T}$. Finally, I take $N = 20000$ draws of these paths. I define:

$$V_{Indep}^{H}(C,\pi) = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} u(c_t^{Indep}, \pi_t^{Indep})\right] \approx \sum_{t=1}^{T} \frac{1}{N} \sum_{n=1}^{N} \beta^{t-1} u(c_{t,n}^{Indep}, \pi_{t,n}^{Indep})$$

$$V_{Base}^{H}(C,\pi) = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} u(c_t^{Base}, \pi_t^{Base})\right] \approx \sum_{t=1}^{T} \frac{1}{N} \sum_{n=1}^{N} \beta^{t-1} u(c_{t,n}^{Base}, \pi_{t,n}^{Base})$$

$$V_{Contr}^{H}(C,\pi,\lambda) = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} u((1+\lambda)c_t^{Contr}, \pi_t^{Contr})\right] \approx \sum_{t=1}^{T} \frac{1}{N} \sum_{n=1}^{N} \beta^{t-1} u((1+\lambda)c_{t,n}^{Contr}, \pi_{t,n}^{Contr})$$

where the three value functions represent, respectively, the value function for the fully independence, baseline and fully controlled model and λ denotes a compensation to households, in terms of units of consumption, in the fully controlled economy. I denote the welfare gain $\lambda^{Baseline}$ as the compensation that would make the households indifferent between living in the fully controlled economy and the baseline economy. Similarly, I define the welfare gain $\lambda^{Independence}$ as the compensation that would make the households indifferent between living in the fully controlled economy and the fully independence economy.

Table B.5 reports the welfare gains of the alternative models relative to the fully controlled economy.

I can observe welfare gains associated to both the baseline model (0.22%) and the fully independence model (0.26%).

In the baseline economy households trade-off lower levels of inflation for lower levels of consumption in the long run. During the transition, households initially enjoy higher levels of consumption owing to lower nominal spreads, which allow the fiscal authority to issue more debt. However, in the long run the higher default rate reduces the average level of consumption. As the gain from lower inflation dominates, welfare is improved. The mechanism is similar in the case of the fully independence economy.

The baseline economy represents already a welfare improvement over an economy where the central banker is fully controlled by the fiscal authority. However, further welfare gains could be obtained by leaving the monetary authority fully independent from political pressures.

1.7 Extensions and Robustness checks

This section extends the baseline model used in the rest of the paper by studying three main variations. The first variation analyzes a model in which debt is riskless and the fiscal authority does not have the option to default; the second variation analyzes a model with tradable and non-tradable goods with downward nominal wage rigidity; the third extension develops a model in which there is a time mismatch between the decisions of the two governmental authorities.

1.7.1 Riskless economy

I present a model in which debt is riskless and the fiscal authority does not have the option to default[31]. The monetary authority takes as given the state (y, b, b', i) and M's value function is:

$$V^M(y, b, b', i) = \max_{\pi} \; (1 - i)u(c) - l(\pi) \tag{1.30}$$

subject to the resource constraint under repayment:

$$c = y - g + q(y, b')\left(b' - (1 - \delta)\frac{b}{\pi}\right) - (r + \delta)\frac{b}{\pi} \tag{1.31}$$

A best inflation response is given by $\hat{\pi}^M(y, b, b', i)$ as the solution to (1.30).

As in the baseline model, the fiscal authority moves first and internalizes M's best inflation response. The associated problem of the fiscal authority is:

$$V^F(y, b) = \max_{i \in [0,1], b'} \; u(c) - l(\pi) - z(y, i) + \beta_F \mathbb{E}_{y'|y}\left[V^F(y', b')\right] \tag{1.32}$$

[31] In other words, in this model the fiscal authority can credibly commit to repay its debts.

subject to (1.31) and:

$$\pi = \hat{\pi}^M(y, b, b', i)$$

The solution to (1.32) yields decision rules for debt issuance $\hat{b}(y, b)$, inflation $\hat{\pi}(y, b)$ and degree of central bank independence $\hat{i}(y, b)$.

The bond price schedule for this economy is given by:

$$q(y, b') = \beta \mathbb{E}_{y'|y}\left[\frac{1}{\hat{\pi}(y', b')}(r + \delta + (1 - \delta)q(y', b''))\right] \tag{1.33}$$

where $b'' = \hat{b}(y', b')$ is next period's bonds policy function.

The timing of the economy is identical to the baseline model. In the appendix I also characterize the Markov Perfect Equilibrium for this alternative model with no default.

I compare the main statistics of the baseline model with the riskless model in Table B.6. For the riskless economy I recalibrate the parameters β_F and z_0 to match the mean level of the debt to GDP ratio and the mean level of the inflation rate of the Brazilian economy. The alternative economy prescribes an average level of *de facto* central bank independence around 95%, higher than the independence level of the baseline model. In addition, the riskless economy displays a much higher level of standard deviation of inflation (3.6% versus 1.7% in the baseline model). All other main statistics are in line with the baseline economy.

1.7.2 Downward nominal wage rigidity

In this section[32] I illustrate a variation of the baseline model with tradable and non-tradable goods with downward nominal wage rigidity which is closesly related to the work by [13]. The existence of such rigidity raises additional sources of inflationary pressure other than debt dilution. In this alternative model households consume both the tradable good, with which they are endowed in every period, and a non-tradable good, which is produced by firms using labor supplied by households.

[32] The details of this alternative model can be found in the Appendix.

Debt is denominated in units of domestic currency and the law of one price holds. Following [33] and [32] we introduce downward nominal wage rigidity in the production of the non-tradable good.

For the monetary authority the benefit of nominal devaluations, i.e. higher tradable inflation is threefold: (i) as in the baseline model it allows to partially dilute the stock of external debt, thus raising consumption of the tradable good; (ii) it allows to directly relax the wage constraint by abating the real wage burden on non-tradable producers, thus raising consumption of the non-tradable good; (iii) it allows to shift resources from tradable to non-tradable consumption through changes in the real exchange rate.

Within this framework the interaction between monetary and fiscal authority is even stronger, since monetary policy can be used not only for debt dilution purposes, but also to ease the effects of nominal rigidities. In bad times, i.e. periods with low realizations of the tradable endowment, the demand for non-tradable goods falls[33]. In turns, such a reduction puts downward pressure on nominal wages. The presence of downward nominal wage rigidity prevents firms from cutting down labor costs hence employment and output in the non-tradable sector falls. The fiscal authority can intervene and reduce pressure on the wage constraint either by issuing more debt, thus increasing consumption of the tradable good, or by exerting more pressure on the monetary authority in order to obtain a higher level of inflation and reduce the effects of nominal rigidities on output and consumption.

This alternative model allows me to capture periods of inflation and reduced central bank independence that are not necessarily associated with higher debt and higher risk. In addition it rationalizes inflation and control during periods of default and financial autarky.

1.7.3 Timing mismatch

In this section I present a modified version of the baseline economy in which there is a timing mismatch between the decisions of the monetary and the fiscal authority. For simplicity, I assume

[33] I use an Armington aggregator for tradable and non-tradable goods. The nature of the CES function allows for some degrees of complementary between the two goods.

that debt is not defaultable and the maturity is 1 period, i.e. $\delta = 1$. At time t the central banker type is appointed by the fiscal authority at time $t-1$, introducing a lag between the optimal decisions of the two authorities.[34]

The fiscal authority moves first, taking as given the best response of the monetary authority, whose type i has been determined in the previous period, and determines the optimal borrowing b' and appoints the central banker i' for the following period. The monetary authority moves second, taking as given all the decisions of the fiscal authority. Given the state (y, b, b', i, i'), M's value function can be represented as:

$$V^M(y, b, b', i, i') = \max_{\pi}(1-i)u(c) - l(\pi) \tag{1.34}$$

subject to the resource constraint under repayment:

$$c = y - g + q(y, b', i')b' - \frac{b}{\pi} \tag{1.35}$$

where $q(y, b', i')$ is the price schedule of government bonds. Notice that, differently from the previous formulation, the price schedule depends on the choice of future central bank independence i', which the monetary authority takes as given. The best inflation response is given by $\pi^M(y, b, b', i, i')$ as the solution to (1.34).

The fiscal authority moves first and internalizes M's inflation response. Given the state (y, b, i), F's value function is given by:

$$V^F(y, b, i) = \max_{i' \in [0,1], b'} \; u(c) - l(\pi) - z(y, i') + \beta_F \mathbb{E}_{y'|y}\left[V^F(y', b', i')\right] \tag{1.36}$$

subject to (1.35) and:

$$\pi = \hat{\pi}^M(y, b, b', i, i')$$

[34]This formulation introduces a new state variable i, since the current degree of central bank independence is taken as given at the beginning of the period.

The solution to (1.36) yields decision rules for debt issuance $\hat{b}(y,b,i)$, inflation $\hat{\pi}(y,b,i)$ and degree of central bank independence $\hat{i}'(y,b,i)$.

The bond price schedule for this economy is given by:

$$q(y,b',i') = \beta\mathbb{E}_{y'|y}\left[\frac{1}{\hat{\pi}(y',b',i')}\right] \tag{1.37}$$

The monetary authority's best inflation response is similar to the condition of the baseline economy and it is given by:

$$l'(\pi) = (1-i)u'(c)\frac{b}{\pi^2} \tag{1.38}$$

The fiscal authority's optimal borrowing decision can be represented as:

$$u'(c)\left(\frac{\partial q}{\partial b'}b' + q\right) + \frac{\partial \pi}{\partial b'}(1-i)u'(c)\frac{b}{\pi^2} = \beta_F\mathbb{E}\left(\frac{u'(c')}{\pi'}\right) - \beta_F\mathbb{E}\left(\frac{\partial \pi'}{\partial b'}(1-i')u'(c')\frac{b'}{\pi'^2}\right) \tag{1.39}$$

As we can see, this condition is equivalent to the condition of the baseline economy in the special case of one-period bonds and non-defaultable debt. The optimal (future) central bank independence decision is given by the condition:

$$\frac{\partial z}{\partial i'} = u'(c)\frac{\partial q}{\partial i'} + (1-i)u'(c)\frac{b}{\pi^2}\frac{\partial \pi}{\partial i'} + \beta_F\mathbb{E}\left((1-i')u'(c')\frac{b'}{\pi'^2}\frac{\partial \pi'}{\partial i'}\right) \tag{1.40}$$

This condition is substantially different from its previous counterpart. The left-hand-side represents the marginal cost of appointing a more independent central banker in the future, while the right-hand-side displays its associated marginal benefit, which is decomposed in three parts. Firstly, appointing a more independent central banker increase consumption in the current period, owing to the positive effect on the price of bonds[35]. Secondly, the appointment of a more independent central banker reduces current period consumption through a lower level of inflation and debt dilution

[35] Under fairly general conditions $\frac{\partial \pi}{\partial i} > 0$. From the pricing condition, this implies that $\frac{\partial q}{\partial i'} > 0$.

caused by higher bond prices.[36] Thirdly, appointing a more independent central banker decreases the level of expected future consumption, owing to expectations of lower future inflation and lower future debt dilution. While the first component increases the marginal benefit of independence, the second and third components decrease the marginal benefit, pushing for higher levels of central bank control. This framework rationalizes forward looking behaviors of the fiscal authority in terms of central banker appointment and helps us understanding how monetary policy can react to shocks with some temporary lags.

1.8 Conclusion

In this paper I studied the degree of *de facto* central bank independence in a setup with sovereign default risk. I showed that central bank independence is determined by the underlying fundamental conditions of the economy and found that central bank independence increases in good times and decreases with higher outstanding levels of debt. I characterized how the endogenous choice of central bank independence affects and distorts the borrowing decision of the fiscal authority and concluded that the result is ambiguous. The model was calibrated to match some moments of Brazil and I found that the implied level of *de facto* central bank independence in the model averages 92% and that this is negatively correlated with debt, inflation and sovereign spread, while it is positively correlated with output. I performed an event an event analysis of the 2015 Brazilian recession to show how this negative episode triggered a reduction of the *de facto* central bank independence and caused higher inflation. I compared the results of my baseline model with two alternative economies and I displayed that debt and default risk is substantially increased the higher is *de facto* central bank independence, while the inflation rate is reduced. Finally, I studied the welfare effects of switching from the baseline economy to the two alternative economies.

In conclusion this paper provides a simple framework to study *de facto* central bank independence

[36]Since $\frac{\partial q}{\partial i'} > 0$, consumption is increased, leading to a lower marginal benefit of inflation, hence lower realized inflation.

in emerging economies with sovereign default risk. I believe that an interesting avenue for future research may be to study whether this framework can determine *de facto* central bank independence in economies with debt issued in foreign currency and in more advanced economies, where debt is essentially riskless.

Chapter 2: Central bank independence, international reserves and disinflation in emerging economies

Over the last decades we have observed a rise in international reserve accumulation and an inflation decline in emerging economies. In this paper we study how central bank independence in these countries accounts for the trends observed in the data by constructing a sovereign default model with two authorities, a fiscal and a monetary authority, in which debt is issued to foreign investors and denominated in local currency. Having an independent central bank allows to accumulate more international reserves and sustain higher levels of external debt at lower default risk than in a consolidated authority model. This leads to two opposing effects on inflation: on the one hand, higher reserves increases consumption lowering its marginal utility and reducing inflation; on the other, higher levels of debt increases the incentives to generate inflation for dilution purposes. The direction and the magnitude of effects depend on the calibration of the model.[1]

2.1 Introduction

Over the past decades, emerging economies increased their international reserves accumulation consistently while reducing inflation rates. The former has been attributed to a number of factors such as income windfalls, increase in roll-over risk and a higher central bank independence, to name a few. A prevalent explanation as to why the latter occurred has been associated with a more disciplined monetary and fiscal policy which helped taming inflation. The fall in inflation rates is of particularly relevance given the recent surge in the participation of local-currency (LC) in public external debt [2]. The incentives to increase inflation to dilute debt are particularly attractive when

[1] Joint work with Rocio Eugenia Suarez.

[2] While foreign-currency (FC) debt is still sizeable, emerging economies were able to overcome their ”original sin”[3] described by [34].

the cost of inflation is relatively low. To foreign investors, this incentive to inflate away real debt may have restricted LC lending to emerging governments during the 1990s when many of them were experiencing periods of hyperinflation. In this paper we study how central bank independence can help rationalize the rise in international reserves and the disinflation in emerging economies given the recent surge in LC public external debt.

We begin this paper by documenting stylized facts involving a sample of 14 emerging economies over the period 2000-2020. In detail, we describe three facts that seem to characterize these countries. First, we find that there is a higher participation of LC public external debt and a surge in international reserves accumulation. Secondly, higher international reserves is associated with lower inflation, a fact that holds both within and across countries. Lastly, the de jure central bank independence has increased.

To illustrate the rationale for these facts, we construct a sovereign default model in which the authority conducting the fiscal policy (i.e. the fiscal authority) and the authority conducting central banking operations (i.e. the monetary policy) are separated, in the style of [29]. In our paper the two authorities have different tools and different objectives available for conducting their policies; their strategic interaction determines the equilibrium of this economy and we assume that the two authorities operate simultaneously. Both authorities have similar preferences in terms of pattern of consumption and inflation, but they differ in their degree of impatience. Similarly to [29] we assume that the fiscal authority is relatively more impatient than the monetary authority, as it is common in the sovereign default literature. This assumption aims at capturing the idea that more independent central banks tend to have objectives that are closer to households. Conversely, governments tend to be more short-sighted and attach a higher weight to current outcomes. The fiscal authority can issue nominal bonds denominated in units of the LC to foreign investors, while the monetary authority can invest in international reserves, which are denominated in units of FC.[4] Additionally, the monetary authority determines the optimal inflation rate of the period.

[4]We assume that both authorities cannot short these financial instruments, i.e. both bonds and reserves are weakly positive. This assumption rules out the case in which both authorities are borrowing (lending) at the same time.

We begin analyzing our model by considering the simpler case of non-defaultable debt, in order to shed light on the mechanism underlying the process of debt issuance, reserve accumulation, and inflation determination. In our model, on the one side, the fiscal authority wants to frontload consumption by borrowing from the rest of the world, as the result of being more impatient than international investors; on the other side, the (independent) monetary authority[5] wants to hold international reserves for consumption smoothing purposes. Essentially, the fiscal authority is willing to deteriorate the net foreign asset position[6], while the monetary authority issues reserves in order to adjust the imbalance. As a result, if the central bank manages to improve the net asset position, the long-run level of consumption is improved, reducing the marginal utility of consumption.

The effects of these open market operations on inflation are ambiguous. Central bank independence leads to more reserves accumulation and the interaction with the fiscal authority can lead to higher borrowing. In turn, higher levels of LC external debt call for higher inflation rates for debt dilution purposes. Simultaneously, improvements in the net foreign asset position reduce the marginal benefit of inflation, as higher inflation has lower impact on consumption, leading to lower desire for inflation. If the former effect prevails, central bank independence is associated with higher inflation, while the prevalence of the latter effect would lead to lower inflation.

The rest of this paper is organized as follows: Section 2.2 describes the literature related to our work; in Section 2.3 we present the empirical evidence motivating this paper; Section 2.4 develops the theoretical model we employ to answer our question; Section 2.5 elaborates the mechanism of the theoretical model; Section 2.6 concludes this paper.

[5]As in [29] we assume that international investors discount the future at a rate β. The fiscal authority's discount factor is $\beta_F < \beta$ and the discount factor of the (independent) monetary authority is $\beta_M = \beta$

[6]We define the net foreign asset position N_t as the difference between the initial stock of reserves and the initial stock of debt (in real terms). If $N_t > 0$ ($N_t < 0$) the country is a net lender to (borrower from) the rest of the world, thus a net exporter (importer).

2.2 Related Literature

This papers builds on four bodies of literature. Firstly, this paper can be related to the literature on quantitative models that aim to shed light on the joint determinants of reserves, debt and default decision given the recent surge of international reserves among emerging economies. [35], perhaps the first to include endogenous international reserves decision in a canonical sovereign default model, find that one-period debt cannot rationalize the levels of international reserves observed in the data since the sovereign could achieve the same net asset position by reducing debt. In such case, holding reserves plays no role as an insurance instrument[7]. [36] focuses on the role of international reserves to improve recovery rates after default while acting as a buffer under the presence of exogenous sudden stops. Meanwhile, [37] studies the role of international reserves to prevent crisis in the context of self-fulfilling rollover crisis. Other papers find that the rollover risk induced by long-maturity debt creates a benefit for holding international reserves, as in [38] [8]. Also under the presence of long-term debt, [32] study the macroeconomic-stabilization hedge of international reserves under the presence of nominal wage rigidities and a fixed exchange rate. In turn, [39] departs from the consolidated sovereign environment by introducing a fiscal authority which issues on-period debt and a monetary one which accumulates reserves. Aside from their objectives both entities differ in their discount factors since a more patient authority is required to accumulate reserves. In this paper, we take a similar approach by decoupling the decisions of debt issuance and reserves accumulation into the two public-sector entities. However, unlike [39], in this paper the monetary authority has as an additional objective of choosing inflation rates, which in turn can have implications on debt dilution and reserves accumulation.

Additionally, this paper relates to the literature that addresses the debt composition of public external debt with a particular focus on the increasing relevance of local currency external debt

[7]Additionally, the assumption of a default cost proportional to output requires a very impatient sovereign to generate the observed debt-to-GDP ratios. This makes it unlikely for the sovereign to accumulate reserves. Lastly, reserves act as a bad insurance against income fluctuation since they make the value of default more attractive.

[8]In this paper, the maturity mismatch between reserves and debt enables the sovereign to use reserves not only to transfer resources from repayment to default states but also within repayment states in which debt is more costly, creating a hedge against rollover risk.

in emerging economies observed since early 2000s. [40] find that the surge of local-currency debt in emerging markets can be accounted for the lower inflation volatility and stronger legal rights of creditors. [2] explore the determinants on this shift by extending a general equilibrium model to include optimal choices of both currency denominations and the monetary policy without commitment. They find that while LC debt issuance acts as a hedge against income shocks, it raises the incentives to dilute debt through inflation or to excessively depreciate real exchange rates. Unlike [2], our paper does not consider the currency composition of sovereign debt by focusing only on LC bonds, but it includes the option to default, which is of secondary importance in their paper. In an empirical study on firms' bond issuance, [41] document that LC denomination increased especially after the 2008 financial crisis with global factors and inflation history of the country being the main determinants of the change in trends. More recently, [42] construct a model that accounts for the surge in LC borrowing in emerging economies in which the sovereign can strategically opt for currency debasement or default on debt. In particular, they find that a government with a less credible monetary policy is more likely to borrow in FC.

[43] combines these two groups of literature by studying international reserves accumulation given the currency denomination of sovereign external debt. However, the debt denomination is exogenously given by comparing the implications of reserves accumulation when debt is fully denominated in LC versus fully denominated in FC. Moreover, in this setup the decision of reserves accumulation and debt issuance is centralized by a single authority when in practice these decisions are usually made by different entities. In their analysis, they find that when sovereign debt ins fully denominated in LC, international reserves have a stronger role as hedge to external shocks. In this paper we depart from [43] since we only consider debt denominated in LC and the choices of reserves accumulation and debt issuance are taken by different authorities.

This paper also refers to the literature that associates central bank independence and inflation, following the seminal work of [18], [19] and [20] who argue that, through discretionary policy, central bank independence can be successful in reducing inflation. [21] is one of the first papers to address the appointment of the central banker through a model in which the market structure heterogeneity determines the conservative central banker. This paper shows that an independent central bank is effectively able to produce a lower level of inflation owing to the elimination of debt dilution incentives. [22] studies how increasing central bank independence can fail to lower the inflation rate in the long-run, as fiscal authorities would use fiscal instruments to decrease current distortions and ultimately leading to an inflationary response by the independent central bank; the author argues that enforcing a strict inflation target would prevent these distortions to happen. [23], [24], [25], [26], [27], empirically study the correlation between central bank independence and the level inflation finding negative results for both developed and emerging economies. A literature review on central bank independence can be found in [28] provides which illustrates the difference between *de jure* and *de facto* independence both in emerging and developed economies.

Finally, we also relate to the literature that discusses debt dilution through inflation. [14] studies this possibility to reduce a country's exposure to self-fulfilling crises, while at the same time the lack of credibility not to inflate in tranquil times makes debt more costly and default more attractive in the event of a crisis. We also explore the implications of generating inflation to debase debt as an alternative to default. [15], [2], [16], [17] and [42] also discuss the debt dilution problem when debt is denominated in LC. [17] studies the trade-off between default and debt dilution, showing the existence of a negative correlation between inflation and default risk, which disagrees with the predictions of my paper, which suggests that the correlation is positive.

2.3 Empirical Evidence

In this section, we want to describe stylized facts about emerging economies regarding their public external debt denominated in local currency, international reserves, inflation and central bank independence during the period 2000-2020. The 14 countries in our sample[9], classified as emerging

[9]The sample of countries include Argentina, Brazil, Bulgaria, China, Egypt, India, Indonesia, Mexico, Peru, Philippines, Russia, South Africa, Thailand and Turkey. Some countries found in the dataset of [30] were excluded given the short-spam data availability.

markets and developing economies by the IMF's World Economic Outlook and low-middle and upper-middle income countries by the World Bank in 2020[10], were determined given the data availability regarding the composition of public external debt. We proceed, first by describing the data to later discuss our main findings.

2.3.1 Data

For the currency denomination of public debt, we use the dataset compiled from from [30] which contains quarterly data of sovereign external debt denominated in foreign and domestic currency. Unfortunately, the data provided by this dataset is available for the period 2004-2020. From now on, whenever we make reference to debt denominated in domestic currency, we will be considering this time period.

Data on international reserves as a percentage of GDP was calculated as the ratio of international reserves -excluding gold- and nominal GDP, denominated in current US dollars. Both series were obtained from World Bank.

For inflation, we used the average annual percentage change of the consumer price index (CPI), also obtained from the World Bank.

Finally, we consider as measure of the de jure central bank independence (CBI) the index constructed by [44] (CBIE), which builds on the two most used measurements of the de jure CBI by [45] (CWN) and [46] (GMT). This index ranges from 0 (no independence) to 1 (full independence) and expands on the dimensions accounted for in the mentioned indexes. The CBIE index considers 42 central bank characteristics over 6 dimensions[11] while including new criteria that accounts for good practices in central bank financial independence and reporting and disclosure. For a detailed description of the CBIE index's components, how it compares to previous indexes of CBI and the change of each CBI index by country, see Appendix I.

[10]Low-middle: Egypt, India, Indonesia and Philippines. Upper-middle: Argentina, Brazil, Bulgaria, China, Mexico, Peru, Russia, South Africa, Thailand and Turkey.

[11]These dimensions are: (1) governor and central bank board, (2) monetary policy and conflict resolution, (3) objectives, (4) limitations on lending to the government, (5) financial independence and (6) reporting and disclosure.

2.3.2 Stylized Facts

From the data, we can gather the following results:

Fact 1: Higher share of LC external debt and international reserves in most emerging economies

Figure A.7A shows the evolution of aggregate international reserves and the aggregate share of total external debt denominated in local currency between 2000 and 2020 (For a detailed description by country, see Appendix I). Each series was computed as the weighted average of the sample using the countries' relative GDP. As mentioned in Section 2.3.1, the lack of data prior to 2004 for the share of public external debt in local currency restricts the analysis. However, it is clear that during this period, these economies changed their currency composition of external debt in favor of local currency while increasing their international reserves holding. Although the surge of international reserves has been a phenomenon since the 1990s in both advanced and emerging economies, the latter have done so at a much faster pace.

Although there is heterogeneity among the countries in the sample, these trends seem to apply for most of the economies studied. Precisely, Figure decomposes the change in international reserves and the share of LC public external debt during the period under study for each country in the sample. In what respects to the change in international reserves accumulation between 2000 and 2020, with the exception of Turkey, Egypt and India, all the countries in the sample increased their reserves holding.

Meanwhile between 2004 and 2020, with the exception of Turkey, these economies either increased or maintained their share of LC external debt, in some cases to the point of changing their entire debt currency portfolio. For instance, India and Thailand maintained their public external debt portfolio denominated fully in LC throughout the period. Countries such as Brazil, China, Peru and Russia reverted their composition, having more than 50% of their public external debt denominated in LC.

Fact 2: Higher international reserves is associated with lower inflation.

Figure A.8 shows the relationship between international reserves and inflation within and between countries. Figure A.8A depicts the unconditional correlation between international reserves and inflation for each country in the sample.

For the majority of the emerging economies in the sample, there seems to be a negative unconditional correlation between international reserves and inflation indicating that countries that hold more international reserves tend to experience lower inflation rates. The negative correlation is preserved across countries as seen in Figure A.8B which shows the scatter plot between reserves and inflation including linear fit.

Fact 3: Higher Central Bank Independence in emerging economies

Lastly, Figure A.9 depicts the evolution and change in the de jure Central Bank Independence index (CBIE) compiled by [44] over the period 2000-2017[12] for the emerging economies in the sample. Figure A.9A shows the evolution of the weighted average CBIE for the emerging economies from 2000 to 2017. Relative to the year 2000, the independence of the monetary authority (i.e central bank) increased consistently over the years.

At the interior of the sample, as shown in Figure A.9B, most countries either increased or maintained their levels of central bank independence, with the exception of Egypt and Argentina. In general, the de jure measures of CBI tend to be stable for long periods of time and experience discrete increases after reforms. If we consider as positive reforms the years in which the CBIE index increased in each country, over the period under study, 10 reforms took place that enhanced the independence of the monetary authorities and three reforms that decreased it[13].

[12]The index spans from 1972 to 2017.

[13]The positive reforms correspond to: Belgium (1), China (1), Indonesia (1), India (2), Mexico (1), Russia (2), Turkey (1), Thailand (1). The negative reforms correspond to: Argentina (2) and Egypt (1). Countries with no change: Peru, Philippines and South Africa.

2.4 Model

2.4.1 The environment

Time is infinite and discrete, indexed by $t \in 0, 1, 2, ...$, and the economy is populated by private and public agents. The former set is constituted by domestic households, who consume their endowment of tradable goods and the transfer received from the government, and by international investors, who engage in financial market operations with the domestic country. The latter set is constituted by the monetary authority, which we will refer to as M, and by the fiscal authority, referred as F.

In this model the fiscal authority finances a transfer to households through net transfer of resources coming from the monetary authority and through the issuance of one-period domestically denominated bonds. The monetary authority sets the domestic inflation rate of the period and engages in the market for international reserves, which are then transferred to the fiscal authority.

Households - In every period households receive an endowment of tradable goods y_t, which follows an exogenous stochastic process given by

$$\log(y_t) = \rho_y \log(y_{t-1}) + \sigma_y \varepsilon_t \tag{2.1}$$

where $\rho_y \in [0, 1]$ and $\sigma_y \in \mathbb{R}^+$ denote, respectively, the persistence and the standard deviation of the stochastic process, and $\varepsilon_t \sim N(0, 1)$.

Households are hand-to-mouth and they employ the endowment received y_t and the transfer T_t received by the fiscal authority to finance private consumption c_t. The period-by-period budget constraint is given by:

$$c_t = y_t + T_t \tag{2.2}$$

Preferences are defined over an infinite stream of consumption and inflation:

$$\mathbb{E}_0 \sum_{t=0}^{+\infty} \beta^t \left(u(c_t) - l(\pi_t)\right) \tag{2.3}$$

where $\beta \in (0,1)$ defines the households' subjective discount factor and π_t defines the gross inflation rate at time t [14]. The instantaneous utility of consumption $u(\cdot)$ is differentiable, increasing and concave and the instantaneous (dis)utility of inflation $l(\cdot)$ is differentiable and convex. Following [2] the disutility from inflation captures distortionary costs associated with inflation [15].

Fiscal and monetary authorities - The fiscal authority (F) transfers resources to households in a lump-sum fashion by redistributing the resources received by the monetary authority (M) and by issuing nominal non-contingent bonds denominated in units of the domestic currency to international investors, which are described later. Following [29] we assume that fiscal support from the monetary authority is always allowed, hence the the monetary authority transfers the net profits (losses) arising from foreign reserve management to the fiscal authority. This assumption allows us to study the consolidated budget constraint of the monetary and fiscal authority: the monetary authority chooses the optimal levels of foreign reserves and inflation rates and the fiscal authority, conditional on not defaulting, chooses the optimal level of borrowing.

In every period, F can either repay its debt, in which case F is in state of repayment (R), or default on its debt, being in state of default (D). In states of default, F is excluded from international financial markets and its budget constraint is given by:

$$T_t = a_t - q_t^a a_{t+1} \tag{2.4}$$

where a_t and a_{t+1} denote, respectively, the initial stock of foreign reserves at the beginning of period t and the stock carried over to the following period, and q_t^a denotes the price of one unit of reserves[16]. Hence, in state D the goods market clearing condition for the tradable good is:

[14] The current-period gross inflation rate is defined as $\pi_t = \frac{P_t}{P_{t-1}}$, where P_t denotes the time t price level.

[15] Distortions from inflation can be rationalized in models with money in the utility function and models with credit and cash goods, as in [2].

[16] Foreign reserves a_t are expressed in terms of units of tradable goods.

$$c_t = y_t + a_t - q_t^a a_{t+1} \tag{2.5}$$

We assume that international investors cannot seize the stock of reserves a_t in states of default. Moreover, we also assume that, in such a state, the monetary monetary has access to the foreign reserves markets a_{t+1}. These assumptions guarantee that the monetary authority is not excluded by international financial markets.

In state R the fiscal authority can issue bonds. The bond is a one-period claim specifying a (nominal) price q_t and a quantity N_t such that the government receives $q_t N_t$ units of domestic currency in period t. The following period, the entire stock of debt $B_t \in \mathbb{R}^+$ matures[17]. The fiscal authority's budget constraint is expressed in real terms and it is given by:

$$T_t = a_t - q_t^a a_{t+1} + q_t b_{t+1} - \frac{b_t}{\pi_t} \tag{2.6}$$

where b_t is the outstanding level of debt in real terms and b_{t+1} is the level of real debt carried over to the next period [18]. Therefore, in state R, the goods market clearing condition of the tradable good is:

$$c_t = y_t + a_t - q_t^a a_{t+1} + q_t b_{t+1} - \frac{b_t}{\pi_t} \tag{2.7}$$

When the fiscal authority defaults on its debt, F is excluded from financial markets and it can reenter with an exogenous probability $\theta \in (0, 1)$ and with no outstanding debt, i.e. $b_t = 0$. Following [6] and [9], we assume that the fiscal authority suffers from direct disutility of default $\phi(y) \in \mathbb{R}$, which is increasing in income. This assumption is intended to capture the fact that, other things equal, F prefers defaulting in bad times rather than in good times.

Given the state of the world D_t, the fiscal authority maximizes the following objective function:

[17]This assumption implies that the nominal issuance N_t corresponds to the the stock of debt carried over to the next period B_{t+1}.

[18]$b_{t+1} \equiv \frac{B_{t+1}}{P_t}$ and $b_t \equiv \frac{B_t}{P_{t-1}}$.

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{+\infty} \beta_F^t \left(u(c_t) - l(\pi_t) - D_t \phi(y_t) \right) \right\} \tag{2.8}$$

where $\beta_F \in (0,1)$ denotes the subjective discount factor of the fiscal authority, which we assume to be lower than the households', i.e. $\beta_F < \beta$, denoting a higher degree of impatience than international investors, which we describe later[19]. Notice that the disutility of default appears only whenever $D_t = 1$, i.e. only states of default.

In a similar fashion, for a given state D_t, the monetary authority maximizes:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{+\infty} \beta_M^t \left(u(c_t) - l(\pi_t) \right) \right\} \tag{2.9}$$

where $\beta_M \in (0,1)$ represents the subjective discount factor of the monetary authority and, similarly to [29], we assume that $\beta_M \geq \beta_F$. This assumption is crucial for the results of this paper, as more independent central banks tend to be more patient than central governments. Additionally, and independently from the degree of central bank independence, we assume that the monetary authority does not incur in disutility losses from outright default.

Nominal exchange rate and international investors - Debt is denominated in units of the domestic currency, hence we need to define a measure of nominal exchange rate that allows foreign investors to convert domestic currency into foreign currency. We define the nominal exchange rate e_t as the price of one unit of foreign currency in terms of local currency. Given this definition, a nominal depreciation episode corresponds to an increase in e_t. We also assume that the law of one price holds i.e. $P_t = e_t P_t^*$, where P_t^* is the price level of the rest of the world. We assume that $P_t^* = 1$ [20], which implies that changes to the nominal exchange rate are entirely determined by changes in domestic fundamentals. International investors are deep pocketed, risk-neutral and discount the future at a rate $\beta = \frac{1}{1+r}$. They purchase nominal sovereign bonds denominated in units of domestic

[19]This assumption ensures that this economy is a net borrower from the rest of the world.

[20]Although not necessary, this assumption allows us to focus on domestic factors affecting the nominal exchange rate. Relaxing this assumption would have no effect on the analysis.

currency from the fiscal authority. The bond price is such that, in expected value, international investors break-even, i.e. they are compensated for any expected loss from default D_{t+1} and from expected nominal exchange rate devaluation $\frac{e_{t+1}}{e_t}$:

$$q_t = \beta \mathbb{E}_t \left((1 - D_{t+1}) \frac{e_t}{e_{t+1}} \right) \tag{2.10}$$

The nominal price of government bonds is decreasing in (expected) default risk and in (expected) nominal exchange rate devaluations.

Exploiting the law of one price allows us to rewrite the bond price schedule as:

$$q_t = \beta \mathbb{E}_t \left(\frac{1 - D_{t+1}}{\pi_{t+1}} \right) \tag{2.11}$$

As it can be observed, the price of domestic government bonds is negatively affected by high levels of expected domestic inflation, which is equivalent to expected nominal exchange rate devaluations.

Foreign reserves are denominated in units of the foreign currency and purchased by the monetary authority from international investors. The price of foreign reserves is such that investors break-even:

$$q_t^a = \beta \tag{2.12}$$

Unlike domestic government bonds, the price of foreign reserves is not affected by exchange rate depreciation, as reserves are denominated in units of foreign currency.

Timing - The timing of actions of this economy is described as follow:

1. The income process y_t realizes and the aggregate state of the economy is given by (y_t, a_t, b_t).
2. The fiscal authority chooses whether to default or not.
    - If default occurs, $D_t = 1$, F is excluded from financial markets and M determines the optimal inflation rate rate π_t and the optimal reserve accumulation a_{t+1};

- If repayment occurs, $D_t = 0$, the fiscal and monetary authorities move simultaneously: F chooses new debt b_{t+1}, given the state (y_t, a_t, b_t) and taking the bond price schedule $q(y_t, a_{t+1}, b_{t+1})$ as given, and M chooses the optimal inflation rate rate π_t and the optimal reserve accumulation a_{t+1};

3. Households consume c_t.

2.4.2 Recursive problem

In this economy the only agents making strategic decisions are the fiscal and the monetary authorities, as households consume their transfer-augmented endowment and international investors demand (supply) bonds (reserves) inelastically at their given price. The environment can be understood as a simultaneous game in which the fiscal authority chooses default and debt, taking as given the monetary authority's best responses, and the monetary authority chooses reserves and inflation, taking as given the fiscal authority's best responses.[21]. We start by looking at the recursive problem of the fiscal authority.

Fiscal authority - Let $V^F(\cdot)$ be the value function of the fiscal authority that faces the state (y, a, b) and let $V_j^F(\cdot)$ be the fiscal authority's value function in state j. The function $V^F(\cdot)$ satisfies the functional equation:

$$V^F(y, a, b) = \max_{D \in \{0,1\}} \left\{ (D) V_D^F(y, a) + (1 - D) V_R^F(y, a, b) \right\} \tag{2.13}$$

where F's value function in state D is represented by:

$$V_D^F(y, a) = u(c) - l(\pi) - \phi(y) + \beta_F \mathbb{E}_{y'|y} \left[\theta V_R^F(y', a', 0) + (1 - \theta) V_D^F(y', a') \right] \tag{2.14}$$

subject to the resource constraint in state D:

$$c = y - q_a a' + a \tag{2.15}$$

[21] We denote current period variables without time index and next period variables with $'$.

and subject to:

$$\pi = \hat{\pi}_D(y, a) \tag{2.16}$$

$$a' = \hat{a}_D(y, a) \tag{2.17}$$

where the former expression represents M's best inflation response and the latter denotes M's best reserve response.

The fiscal authority's value function in state R can be seen as:

$$V_R^F(y, a, b) = \max_{b'} \; u(c) - l(\pi) + \beta_F \mathbb{E}_{y'|y}\left[V^F(y', a', b')\right] \tag{2.18}$$

subject to the resource constraint:

$$c = y - q_a a' + a + q(y, a', b')b' - \frac{b}{\pi} \tag{2.19}$$

and subject to the expressions:

$$\pi = \hat{\pi}_R(y, a, b) \tag{2.20}$$

$$a' = \hat{a}_R(y, a, b) \tag{2.21}$$

with the former expression indicating M's best inflation response and the latter M's best reserve response in state R.

The solution to (2.13) yields decision rules for default, $\hat{D}(y, a, b)$ and debt issuance $\hat{b}(y, a, b)$. The decision rule for default equals 1 if the fiscal authority defaults and 0 otherwise.

Monetary authority - Let $V_j^M(\cdot)$ denote the monetary authority's value function in state $j = \{D, R\}$ where, as already described, *D* denotes the state of default and *R* the state of repayment. In state $j = D$ the monetary authority takes as given the state (y, a) and M's value function is given by:

$$V_D^M(y, a) = \max_{\pi, a'} \; u(c) - l(\pi) + \beta_M \mathbb{E}_{y'|y}\left[\theta V_R^M(y', a', 0) + (1 - \theta)V_D^M(y', a')\right] \tag{2.22}$$

subject to the resource constraint under default:

$$c = y - q_a a' + a \tag{2.23}$$

The solution to (2.22) yields decision rules for inflation $\hat{\pi}_D(y, a)$ and reserves $\hat{a}_D(y, a)$ in states of default.

In state $j = R$ the monetary authority takes as given the state (y, a, b), and M's value function is:

$$V_R^M(y, a, b) = \max_{\pi, a'} \quad u(c) - l(\pi) + \beta_M \mathbb{E}_{y'|y} \left[D' \cdot V_D^M(y', a') + (1 - D') \cdot V_R^M(y', a', b') \right] \quad (2.24)$$

subject to the resource constraint under repayment:

$$c = y - q_a a' + a + q(y, a', b')b' - \frac{b}{\pi} \quad (2.25)$$

and subject to the expressions:

$$b = \hat{b}_R(y, a, b) \quad (2.26)$$

$$D' = \hat{D}(y', a', b') \quad (2.27)$$

which represent, respectively, F's best borrowing response and the (future) default decision.

The solution to (2.24) yields decisions rules for inflation $\hat{\pi}_R(y, a, b)$ and reserves $\hat{a}_R(y, a, b)$ in states of repayment.

Bond price schedule - International investors price domestic bonds with the price schedule:

$$q(y, a', b') = \beta \mathbb{E}_{y'|y} \left[\frac{1 - \hat{D}(y', a', b')}{\hat{\pi}(y', a', b')} \right] \quad (2.28)$$

We can now define the Markov perfect equilibrium of this economy.

Definition 2 (Markov Perfect Equilibrium) *A Markov perfect equilibrium for this economy is defined as:*

(i) a set of value functions $V_R^M(y, a, b)$*,* $V_D^M(y, a)$*,* $V^F(y, a, b)$*,* $V_R^F(y, a, b)$*,* $V_D^F(y, a)$*;*

(ii) *associated policy functions for default* $\hat{D}(y,a,b)$*, borrowing* $\hat{b}(y,a,b)$*, reserves accumulation* $\hat{a_R}(y,a,b)$ *and* $\hat{a_D}(y,a)$*, inflation* $\hat{\pi_R}(y,a,b)$ *and* $\hat{\pi_D}(y,a)$*, consumption* $\hat{c}(y,a,b)$*;*

(iii) *a bond price schedule* $\hat{q}(y,a',b')$*;*

such that:

(a) *Given the state* (y,a)*, the policy functions* $\{\hat{a_D}(y,a),\hat{\pi_D}(y,a)\}$ *solve the optimization problem* (2.22)*;*

(b) *Given the state* (y,a,b) *and the bond price schedule, the policy functions* $\{\hat{a_R}(y,a,b),\hat{\pi_R}(y,a,b)\}$ *solve the optimization problem* (2.24)*;*

(c) *Given the state* (y,a,b) *and the bond price schedule, the policy functions* $\{\hat{D}(y,a,b),\hat{b}_R(y,a,b)\}$ *solve the optimization problems* (2.13)*,* (2.14)*,* (2.18)*;*

(d) *Given the bond price schedule and the other policy functions,* $\hat{c}(y,a,b)$ *satisfies the resource constraint;*

(e) *The bond price schedule satisfies* (2.28)*.*

In the next section we will dig deeply into the mechanism of our model and explain the driving forces of the authorities' decisions.

2.5 Mechanism

We now study the problem faced by the monetary and the fiscal authorities in our framework. For the reminder of this section we will assume that the fiscal authority can commit to repay its debt in every period.[22] This assumption entails that the fiscal authority cannot default and it has always access to international financial markets, which allows us to study the problem of the two authorities only in states of repayment.

[22]This assumption will help us deriving analytical first order conditions for the problem faced by the two authorities.

Inflation and reserves accumulation - Taking as given the policy function $\hat{b}_R(y,a,b)$ and the state (y,a,b), the monetary authority chooses the level of inflation π that maximize its value function $V_R^M(y,a,b)$, which yield the following expression:

$$\overbrace{l'(\pi)}^{\text{marginal cost of inflation}} \quad = \quad \overbrace{u'(c)\frac{b}{\pi^2}}^{\text{marginal benefit of inflation}} \tag{2.29}$$

where the left-hand-side represents the marginal cost of one extra unit of (gross) inflation and the right-hand-side denotes its associated marginal benefit. As we can see, the marginal cost of inflation is represented by the increase in the disutility associated with higher prices, while the marginal benefit is given by the extra utility of consumption generated by the reduction in the real value of the outstanding debt.

In a similar fashion, the optimal reserves accumulation rule a' maximizes the value function of the monetary authority $V_R^M(y,a,b)$, which is given by:

$$\overbrace{u'(c)\left(q_a - \frac{\partial q}{\partial a'}b'\right)}^{\text{marginal cost of reserves}} = \overbrace{\beta_M \mathbb{E}\left(u'(c')\right) + \underbrace{\beta_M \mathbb{E}\left(u'(c')\left(\frac{\partial q'}{\partial b''}\frac{\partial \hat{b}'}{\partial a'}b'' + \frac{\partial \hat{b}'}{\partial a'}q'\right)\right)}_{\text{reserves distortion}}}^{\text{marginal benefit of reserves}} \tag{2.30}$$

where the left-hand-side and the right-hand-side portray, respectively, the marginal cost of one extra unit of international reserves and its (expected) marginal benefit. The marginal cost of higher reserves accumulation is twofold: firstly, it reduces the resources available for current consumption and, secondly, it affects current consumption through its indirect effect on the price of new debt issuance. The marginal benefit of reserves is given by two factors: on the one side higher reserves accumulation increase future consumption, on the other side it affects the future response of borrowing by the fiscal authority. This last effect is a distortion caused by the presence of a dual regime and its sign depends on how borrowing decisions are affected by changes in the initial level of reserves $\frac{\partial \hat{b}'}{\partial a'}$.

Borrowing - Taking as given the policy functions $\hat{\pi}_R(y,a,b)$ and $\hat{a}_R(y,a,b)$ and the state

(y, a, b), the fiscal authority chooses the level of borrowing b' that maximizes its value function $V_R^F(y, a, b)$, which can represented as:

$$\overbrace{u'(c)\left(\frac{\partial q}{\partial b'}b' + q\right)}^{\text{marg. ben. of borrowing}} = \overbrace{\beta_F \mathbb{E}\left(\frac{u'(c')}{\pi'}\right) - \underbrace{\beta_F \mathbb{E}\left(u'(c')\left(\frac{\partial q'}{\partial a''}\frac{\partial \hat{a}'}{\partial b'}b'' - \frac{b'}{\pi'^2}\frac{\partial \hat{\pi}'}{\partial b'}\right) - l'(\pi')\frac{\partial \hat{\pi}'}{\partial b'}\right)}_{\text{borrowing distortions}}}^{\text{mar. cost of borrowing}} \quad (2.31)$$

where the left hand side denotes the marginal benefit of one extra unit of borrowing, and the right hand side displays its (expected) marginal cost. At the optimum, the fiscal authority will equalize these two quantities.

On the one side, the marginal benefit of borrowing is positively affected by additional per unit revenues q and negatively affected by the price drop on all units of borrowing $\frac{\partial q}{\partial b'}b'$; on the other side, the marginal cost of borrowing is affected by the expected marginal cost and by distortions generated by the interaction between the monetary and the fiscal authority. These distortions arise from the expectation of the fiscal authority about future changes in reserve accumulation and inflation caused by changes in current borrowing levels: firstly, a higher current level of borrowing will stimulate a higher expected inflation response and, secondly, it will stimulate higher future reserve accumulation by the monetary authority.

In equilibrium, the combination of (2.29) with (2.32) leads us to the following simpler expression:

$$u'(c)\left(\frac{\partial q}{\partial b'}b' + q\right) = \beta_F \mathbb{E}\left(\frac{u'(c')}{\pi'}\right) - \beta_F \mathbb{E}\left(u'(c')\frac{\partial q'}{\partial a''}\frac{\partial \hat{a}'}{\partial b'}b''\right) \quad (2.32)$$

As we can observe, the borrowing distortions are simply represented by the change in future consumption induced by changes in borrowing costs caused by changes in reserves accumulation from the monetary authority. This effect, as well as the reserves accumulation distortion, is caused by the presence of a dual regime.

Single authority problem and model comparison - We now consider the problem faced by a country in which there is a single authority that issues debt, invest in international reserves and determines the optimal inflation rate of the economy. We assume that the fiscal authority is the only authority in the country and it has a discount factor β_F. Firstly, the inflation optimality condition of this economy is identical to our benchmark model, and it is given by (2.29). This implies that the nature of the monetary regime does not influence the optimal inflation of this economy. Secondly, the borrowing decision of the single authority is represented by:

$$u'(c)\left(\frac{\partial q}{\partial b'}b' + q\right) = \beta_F \mathbb{E}\left(\frac{u'(c')}{\pi'}\right) \tag{2.33}$$

As we can see, having a single authority eliminates the borrowing distortions generated by the presence of a dual regime. Thirdly, the reserves accumulation decision is given by the following expression:

$$u'(c)\left(q_a - \frac{\partial q}{\partial a'}b'\right) = \beta_F \mathbb{E}\left(u'(c')\right) \tag{2.34}$$

The reserves accumulation optimality condition differs from its previous counterpart for two reasons. Similarly to the borrowing condition, having a single authority eliminates the distortions due to the dual regime's problem. Additionally, the expected marginal benefit of one extra unit of reserves is evaluated with fiscal authority's discount factor β_F, which we assumed to be smaller than the monetary authority's discount factor β_M. Absent distortions in the dual regime and given the same state of the world (y, a, b), the marginal benefit of investing in international reserves is lower in a single regime economy. The intuition for this result is simple: in a single regime economy, the only authority conducting the operations is the fiscal authority, while in a dual regime, international reserves are accumulated by the monetary authority, who is more patient than the fiscal authority, hence it will try to save more in order to better smooth consumption.

The overall effect of the different monetary regimes on inflation is non-trivial. Let us focus on (2.29) and, for the sake of our argument, let us assume that more international reserves are accumulated in a dual regime economy. Holding more reserves leads to higher levels of consumption, thus reducing its marginal utility. If the higher level of reserves leads to lower borrowing from the fiscal authority, the marginal benefit of inflation will decline, leading to lower inflation in equilibrium. Viceversa, if the higher level of reserves leads to higher borrowing from the fiscal authority[23], the effect on inflation will depend on the functional forms and the calibration of the model. On the one hand, higher borrowing levels will require the monetary authority to raise inflation, as the burden of repayment is higher. On the other hand, the increase in reserves accumulation might still be sufficient enough to reduce the marginal utility of consumption and compensate for the higher required debt dilution, thus reducing the marginal benefit of inflation. If the latter effect prevails, having a dual regime economy will still lead to lower inflation rates than in a single regime. A similar intuition can be extended to the case in which debt is defaultable.

Therefore, the mechanism explaining the role of reserves in reducing inflation comes from the positive effect on consumption, which reduces the marginal utility of consumption and, consequently, the marginal benefit of inflation.

2.6 Conclusion

In this paper we propose a model that aims to account for the implications of higher central bank independence in emerging economies and how this helps explaining the increase in LC public external debt and international reserves accumulation over the past two decades.

In our model there are two different authorities, the fiscal and the monetary authority, with different tools and objectives for conducting their policies. Having these two separate entities allows to sustain higher international reserves as a consequence of a more patience monetary authority while the fiscal authority is willing to deteriorate the net foreign asset position.

The effects on debt issuance and reserves accumulation on inflation are ambiguous. Higher international reserves can lead to higher borrowing from the fiscal authority, increasing the debt dilution incentives while at the same time, an improvement in the net asset position reduces the

[23]This scenario is plausible if the increase in reserve accumulation leads to a strong reduction in the price of government bonds, thus increasing the marginal benefit of borrowing.

benefits of inflation on consumption. The direction and magnitude of these opposing effects will be determined by the calibration of the model.

References

1. Dincer, N. N. & Eichengreen, B. Central Bank Transparency and Independence: Updates and New Measures. *International Journal of Central Banking* **10,** 189–259 (2014) (cited on p. 1).
2. Ottonello, P. & Perez, D. J. The Currency Composition of Sovereign Debt. *American Economic Journal: Macroeconomics* **11,** 174–208 (2019) (cited on pp. 2, 6, 8, 9, 13, 25, 46, 47, 52).
3. Engel, C. & Park, J. *Debauchery and Original Sin: The Currency Composition of Sovereign Debt* NBER Working Papers 24671 (National Bureau of Economic Research, Inc, 2018) (cited on pp. 2, 6).
4. Eaton, J. & Gersovitz, M. Debt with Potential Repudiation: Theoretical and Empirical Analysis. *Review of Economic Studies* **48,** 289–309 (1981) (cited on pp. 3, 5).
5. Aguiar, M. & Gopinath, G. Defaultable debt, interest rates and the current account. *Journal of International Economics* **69,** 64–83 (2006) (cited on pp. 3, 5).
6. Arellano, C. Default Risk and Income Fluctuations in Emerging Economies. *American Economic Review* **98,** 690–712 (2008) (cited on pp. 3, 5, 14, 53).
7. Aguiar, M. & Amador, M. in *Handbook of International Economics* (eds Gopinath, G., Helpman, . & Rogoff, K.) 647–687 (Elsevier, 2014) (cited on p. 5).
8. Hatchondo, J. C. & Martinez, L. Long-duration bonds and sovereign defaults. *Journal of International Economics* **79,** 117–125 (2009) (cited on pp. 5, 13).
9. Chatterjee, S. & Eyigungor, B. Maturity, Indebtedness, and Default Risk. *American Economic Review* **102,** 2674–99 (2012) (cited on pp. 5, 14, 53).
10. Arellano, C., Bai, Y. & Mihalache, G. *Monetary Policy and Sovereign Risk in Emerging Economies (NK-Default)* NBER Working Paper No. 26671. 2020 (cited on pp. 5, 6, 27).
11. Dvorkin, M., Sánchez, J. M., Sapriza, H. & Yurdagul, E. Sovereign Debt Restructurings. *American Economic Journal: Macroeconomics* **13,** 26–77 (2021) (cited on p. 6).
12. Gordon, G. *Efficient Computation with Taste Shocks* Working Paper 19-15 (Federal Reserve Bank of Richmond, 2019) (cited on p. 6).
13. Na, S., Schmitt-Grohé, S., Uribe, M. & Yue, V. The Twin Ds: Optimal Default and Devaluation. *American Economic Review* **108,** 1773–1819. doi:10.1257/aer.20141558 (2018) (cited on pp. 6, 36, 85).

14. Aguiar, M., Amador, M., Farhi, E. & Gopinath, G. *Crisis and Commitment: Inflation Credibility and the Vulnerability to Sovereign Debt Crises* NBER Working Papers 19516 (National Bureau of Economic Research, Inc, 2013) (cited on pp. 6, 31, 47).

15. Hur, S., Kondo, I. & Perri, F. Real Interest Rates, Inflation, and Default. CEPR Discussion Paper (2018) (cited on pp. 6, 47).

16. Sunder-Plassmann, L. Infation, default and sovereign debt: The role of denomination and ownership. *Journal of International Economics* **127** (2020) (cited on pp. 6, 47).

17. Galli, C. Inflation, Default Risk and Nominal Debt. Working Papers (2020) (cited on pp. 6, 47).

18. Kydland, F. E. & Prescott, E. C. Rules Rather Than Discretion: The Inconsistency of Optimal Plans. *Journal of Political Economy* **85,** 473–491 (1977) (cited on pp. 7, 46).

19. Barro, R. J. & Gordon, D. B. Rules, discretion and reputation in a model of monetary policy. *Journal of Monetary Economics* **12,** 101–121 (1983) (cited on pp. 7, 46).

20. Rogoff, K. The Optimal Degree of Commitment to an Intermediate Monetary Target. *The Quarterly Journal of Economics* **100,** 1169–1189 (1985) (cited on pp. 7, 46).

21. Waller, C. J. A bargaining model of partisan appointments to the central bank. *Journal of Monetary Economics* **29,** 411–428. doi:https://doi.org/10.1016/0304-3932(92)90034-Y (1992) (cited on pp. 7, 46).

22. Martin, F. M. Debt, inflation and central bank independence. *European Economic Review* **79,** 129–150 (2015) (cited on pp. 7, 47).

23. Alesina, A. & Summers, L. H. Central Bank Independence and Macroeconomic Performance: Some Comparative Evidence. *Journal of Money, Credit and Banking* **25,** 151–162 (1993) (cited on pp. 7, 47).

24. Walsh, C. E. in *The New Palgrave Dictionary of Economics* 2nd Edition. Chap. 0 (Palgrave Macmillan, 2008) (cited on pp. 7, 47).

25. Cukierman, A. Central bank independence and monetary policymaking institutions – Past, present and future. *European Journal of Political Economy* **24,** 722–736 (2008) (cited on pp. 7, 11, 47).

26. Waller, C. J. Independence + accountability: why the Fed is a well-designed central bank. *Review* **93,** 293–302 (2011) (cited on pp. 7, 47).

27. Garriga, A. C. & Rodriguez, C. M. More effective than we thought: Central bank independence and inflation in developing countries. *Economic Modelling* **85,** 87–105 (2020) (cited on pp. 7, 11, 47).

28. Dall'Orto Mas, R., Vonessen, B., Fehlker, C. & Arnold, K. *The case for central bank independence: a review of key issues in the international debate* Occasional Paper Series 248 (European Central Bank, 2020) (cited on pp. 7, 10, 11, 47).
29. Samano, A. *International Reserves and Central Bank Independence* Policy Research Working Paper Series 9832 (The World Bank, 2021) (cited on pp. 7, 33, 43, 44, 52, 54).
30. Arslanalp, M. S. & Tsuda, M. T. *Tracking Global Demand for Emerging Market Sovereign Debt* tech. rep. 2014/039. IMF Working Papers (International Monetary Fund, 2014) (cited on pp. 8, 47, 48, 74, 87, 89).
31. Cuadra, G., Sanchez, J. M. & Sapriza, H. Fiscal policy and default risk in emerging markets. *Review of Economic Dynamics* **13,** 452–469. doi:https://doi.org/10.1016/j.red.2009.07.002 (2010) (cited on p. 13).
32. Bianchi, J. & Sosa-Padilla, C. *Reserve Accumulation, Macroeconomic Stabilization, and Sovereign Risk* Working Paper 27323 (National Bureau of Economic Research, 2020). doi:10.3386/w27323 (cited on pp. 26, 37, 45, 85).
33. Schmitt-Grohé S., U. M. Pegs and Pain. *NBER Working Papers 16847* (2011) (cited on p. 37).
34. Eichengreen, B., Hausmann, R. & Panizza, U. in *Capital Controls and Capital Flows in Emerging Economies: Policies, Practices, and Consequences* 121–170 (National Bureau of Economic Research, Inc, 2007) (cited on p. 42).
35. Alfaro, L. & Kanczuk, F. Optimal reserve management and sovereign debt. *Journal of International Economics* **77,** 23–36 (2009) (cited on p. 45).
36. Tavares, T. The Role of International Reserves in Sovereign Debt Restructuring under Fiscal Adjustment. Working Papers (2018) (cited on p. 45).
37. Hernandez, J. How International Reserves Reduce the Probability of Debt Crises. Working Papers (2018) (cited on p. 45).
38. Bianchi, J., Hatchondo, J. C. & Martinez, L. International Reserves and Rollover Risk. *American Economic Review* **108,** 2629–2670 (2018) (cited on p. 45).
39. Samano, A. International reserves and central bank independence. *Journal of International Economics* **139,** 103674. doi:https://doi.org/10.1016/j.jinteco.2022.103674 (2022) (cited on p. 45).
40. Burger, J. D., Warnock, F. E. & Warnock, V. C. Emerging Local Currency Bond Markets. *Financial Analysts Journal* **68,** 73–93 (2012) (cited on p. 46).
41. Hale, G. B., Jones, P. C. & Spiegel, M. M. Home currency issuance in international bond markets. *Journal of International Economics* **122,** 103256 (2020) (cited on p. 46).

42. Engel, C. & Park, J. Debauchery and Original Sin: The Currency Composition of Sovereign Debt. *Journal of the European Economic Association* **20,** 1095–1144 (2022) (cited on pp. 46, 47).

43. Alfaro, L. & Kanczuk, F. Debt Redemption and Reserve Accumulation. *IMF Economic Review* **67,** 261–287 (2019) (cited on p. 46).

44. Romelli, D. The political economy of reforms in Central Bank design: evidence from a new dataset. *Economic Policy* **37,** 641–688. doi:10.1093/epolic/eiac011. eprint: https://academic.oup.com/economicpolicy/article-pdf/37/112/641/48354123/eiac011_supplementary_data.pdf (2022) (cited on pp. 48, 50, 75, 87, 90, 91).

45. Cukierman, A., Webb, S. B. & Neyapti, B. Measuring the Independence of Central Banks and Its Effect on Policy Outcomes. *The World Bank Economic Review* **6,** 353–398 (1992) (cited on pp. 48, 90, 91).

46. Grilli, V., Masciandaro, D. & Tabellini, G. Political and monetary institutions and public financial policies in the industrial countries. *Economic Policy* **6,** 341–392. doi:10.2307/1344630. eprint: https://academic.oup.com/economicpolicy/article-pdf/6/13/341/7094774/economicpolicy6-0341.pdf (2014) (cited on pp. 48, 90, 91).

47. Schmitt-Grohe, S. & Uribe, M. Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment. *Journal of Political Economy* **124,** 1466–1514 (2016) (cited on p. 85).

48. Jácome, L. I. & Vázquez, F. Is there any link between legal central bank independence and inflation? Evidence from Latin America and the Caribbean. *European Journal of Political Economy* **24.** Does central bank independence still matter?, 788–801. doi:https://doi.org/10.1016/j.ejpoleco.2008.07.003 (2008) (cited on pp. 90, 91).

Appendix A: Figures

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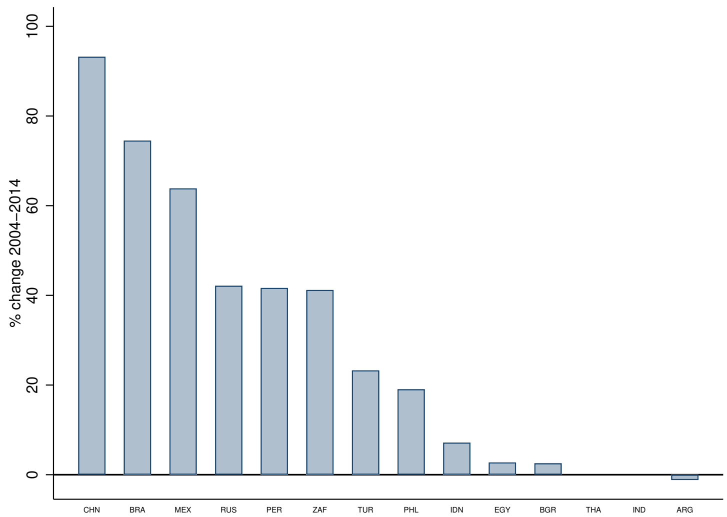
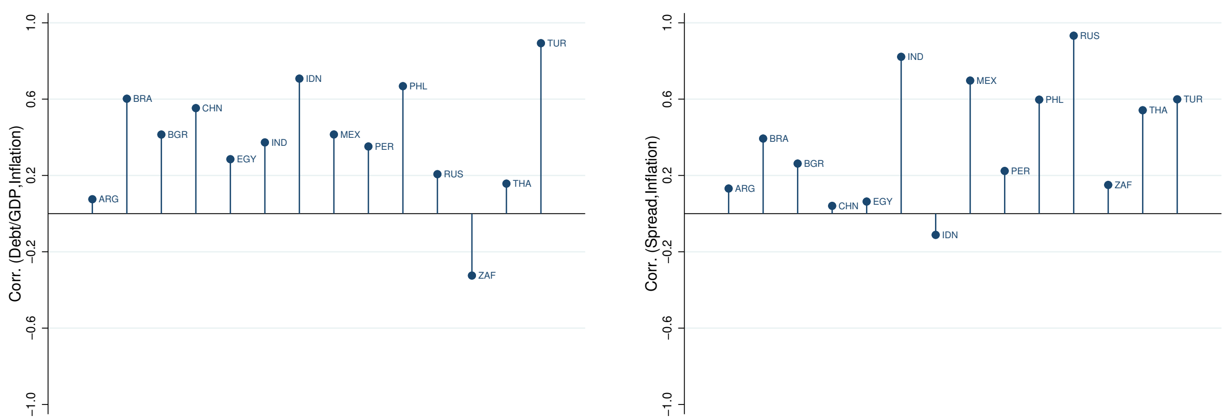


Figure A.1: Change in debt issued in local currency



(A) Correlation Debt/GDP-Inflation

(B) Correlation Spread-Inflation

Figure A.2: Correlations with inflation

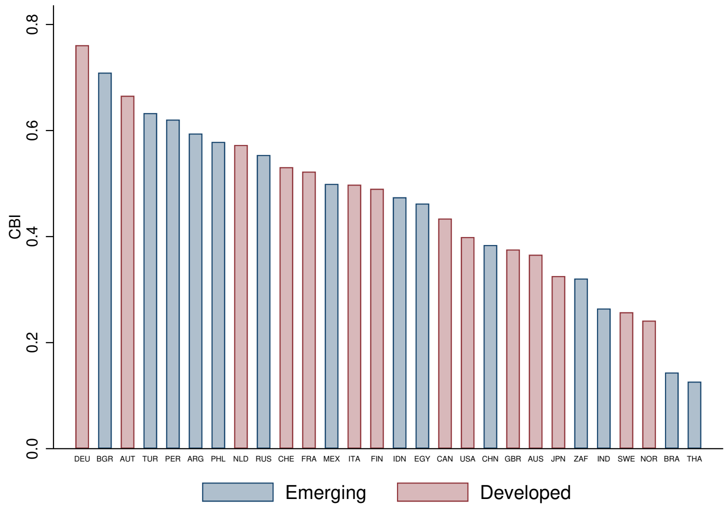


Figure A.3: De jure central bank independence indicator

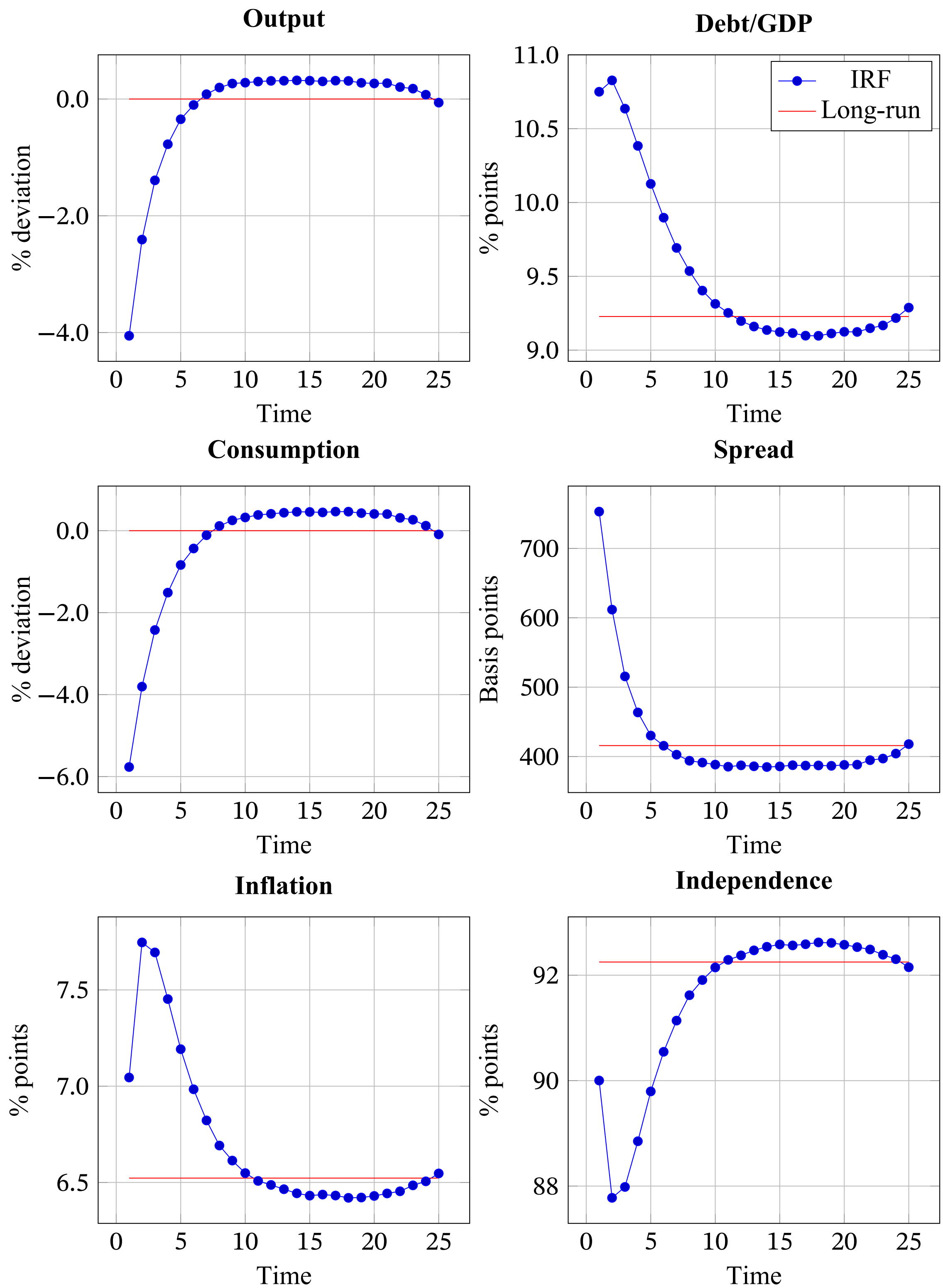


Figure A.4: Impulse response functions

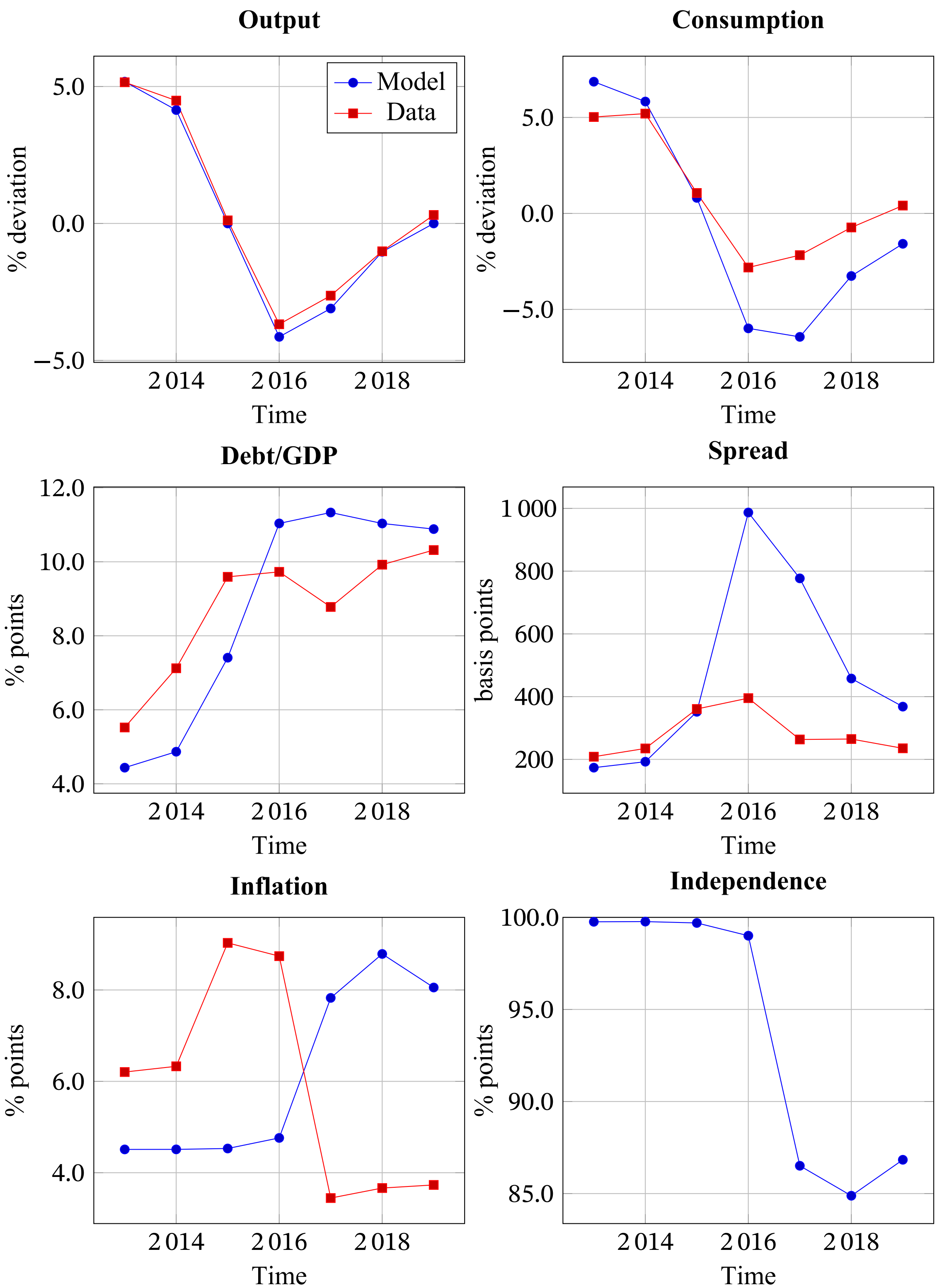


Figure A.5: Event analysis

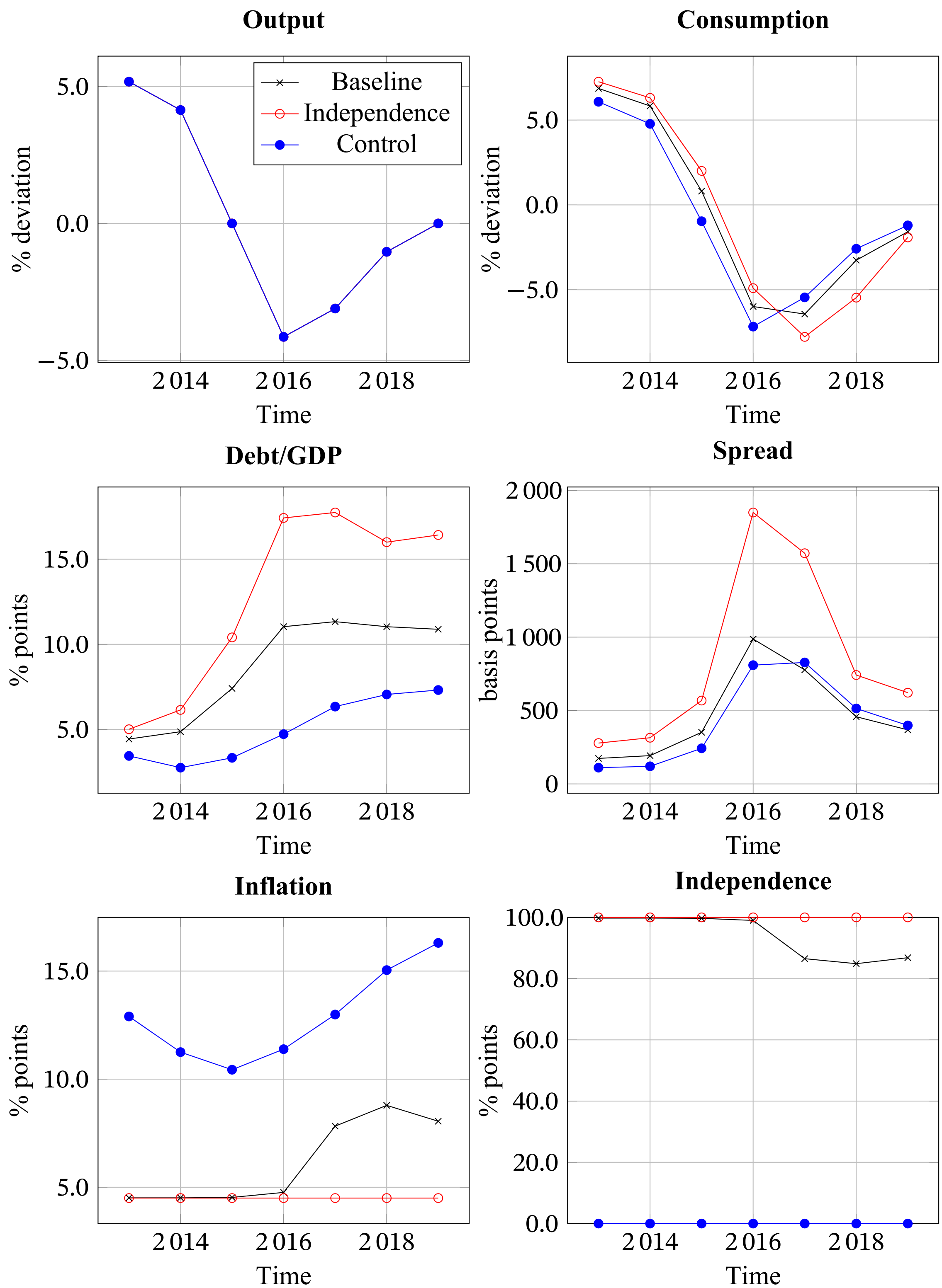
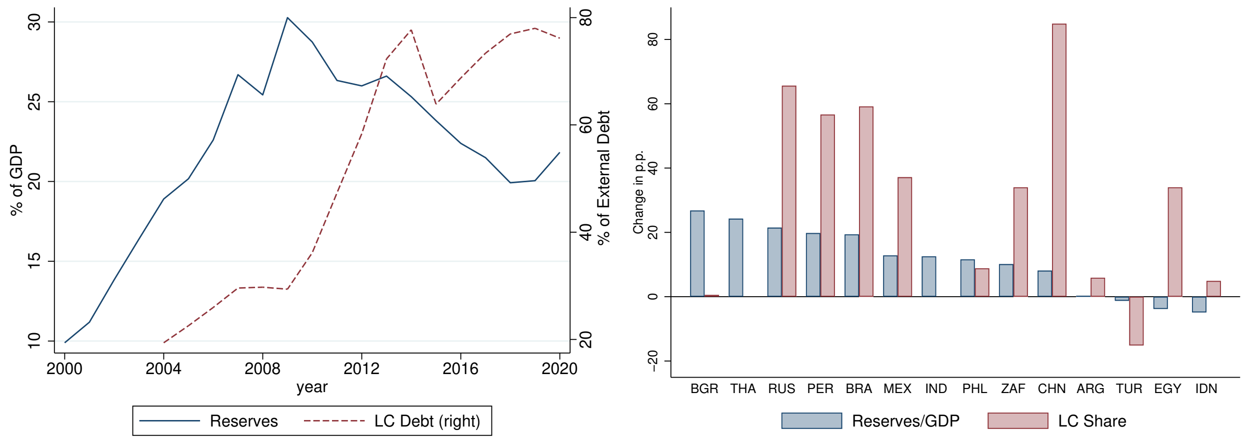
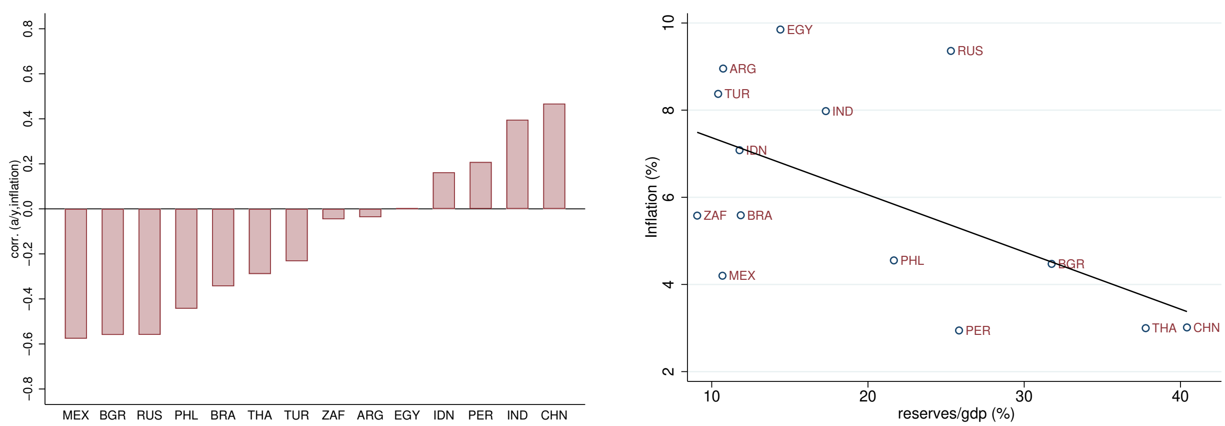


Figure A.6: Counterfactual event analysis



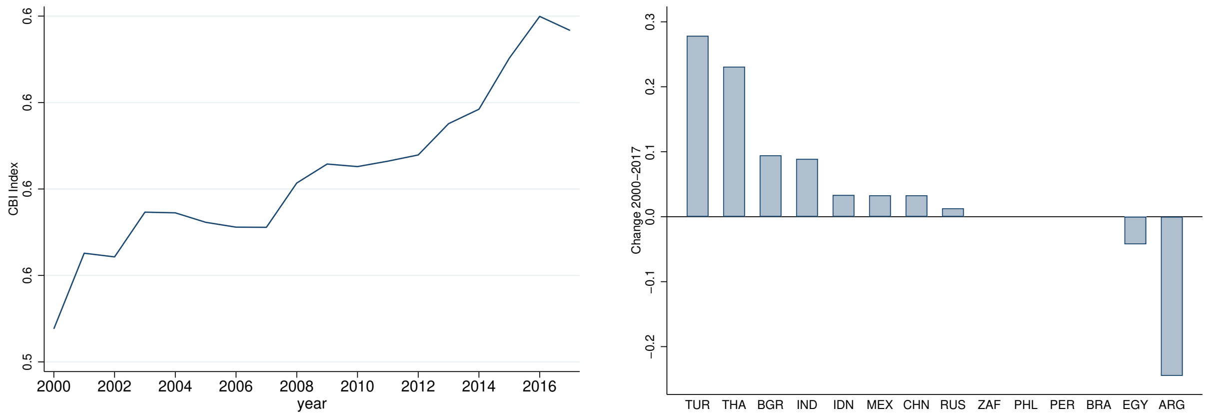
(A) Aggregate Int. Reserves and LC Debt (B) Change in Reserves and LC Debt

Figure A.7: International Reserves and LC Debt in 2000-2020
Note: International reserves as a % of GDP from World Bank for the period 2000-2020, weighted average according to their relative GDP. The share of public external debt in local currency (LC) over the period 2004–2020 from [30]. For the case of Brazil and Bulgaria, the data begins in 2005 while for South Africa data begins in 2006.



(A) International Reserves and Inflation (B) International Reserves and Inflation

Figure A.8: Effect of External Debt and Reserves on inflation
Note: International reserves as a % of GDP and inflation rates for the period 2000-2020 from World Bank.



(A) CBI Index 2000-2017

(B) Change in Index 2000-2017

Figure A.9: Central Bank Independence Index

Note: Central Bank Independence Index from [44] for the period 2000-2017. The index ranges from 0 to 1 and considers 42 characteristics of central banks.

Appendix B: Tables

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Table B.1: Parametrization

Description		Value	Target
Parameters from literature and data			
Risk aversion	σ	3	Standard value
Inflation disutility	χ	1	Normalization
Persistence of y	ρ_y	0.6	Cyclical component GDP
Variance of y	σ_y	0.02	Cyclical component GDP
Investors' discount rate	r	0.011	Average return US T-Bills
Reentry probability	θ	0.2	Average length default episode
Public expenditure	g	0.3832	Average spending/GDP ratio
Average debt maturity	δ	0.1422	Average duration bonds
Inflation target	$\bar{\pi}$	1.045	Average official CB target
Parameters from simulations			
Fiscal authority's discount factor	β_F	0.94	6.2% average inflation rate
Default disutility cost (constant)	α_0	0.17	9.8% average debt/GDP ratio
Default disutility cost (linear)	α_1	5.8	412 bps average
CB control cost	z_0	0.057	0.57 inflation-spread correlation

Table B.2: Model statistics

Moment	Data	Model
Targeted moments		
Mean debt/GDP (%)	9.8	9.2
Mean inflation (%)	6.2	6.5
Mean spread (bps)	412	417
Spread, inflation correlation	0.57	0.56
Untargeted moments		
St. deviation spread (bps)	305	384
St. deviation inflation (%)	2.6	1.7
Consumption, output correlation	0.94	0.98
Inflation, Debt/GDP correlation	0.49	0.71
Spread, Debt/GDP correlation	0.87	0.55
Spread, GDP correlation	-0.45	-0.85
Debt/GDP, GDP correlation	-0.66	-0.76

Table B.3: Central bank independence statistics

Moment	Model
Mean (%)	92
Standard deviation (%)	6
Correlations with independence	
- Debt/GDP	-0.72
- Inflation	-0.64
- Spread	-0.57
- Output	0.64

Table B.4: Counterfactual statistics

Moment	**Baseline**	**Full Independence**	**Full Control**
Mean debt/GDP (%)	9.2	14.7	5.6
Mean inflation (%)	6.5	4.5	13.3
Mean spread (bps)	417	638	455
St. deviation spread (bps)	384	472	689
St. deviation inflation (%)	1.7	0	5.9
Spread, inflation correlation	0.56	0	0.43
Consumption, output correlation	0.98	0.96	0.99
Inflation, Debt/GDP correlation	0.71	0	0.93
Spread, Debt/GDP correlation	0.55	0.5	0.68
Spread, GDP correlation	-0.85	-0.87	-0.74
Debt/GDP, GDP correlation	-0.76	-0.66	-0.63

Table B.5: Welfare analysis

Welfare gain	**%**
Fully controlled-reference	0.000
(i) Baseline	0.22
(ii) Fully independence	0.26

Table B.6: Baseline vs no-default model

Moment	Baseline	No-default
Mean debt/GDP (%)	9.2	9.8
Mean inflation (%)	6.5	6.6
Mean independence (%)	92.0	95.0
Mean spread (bps)	417	-
St. deviation spread (bps)	384	-
St. deviation inflation (%)	1.7	3.6
Spread, inflation correlation	0.56	-
Consumption, output correlation	0.98	0.98
Inflation, Debt/GDP correlation	0.71	0.78
Spread, Debt/GDP correlation	0.55	-
Spread, GDP correlation	-0.85	-
Debt/GDP, GDP correlation	-0.76	-0.8

Appendix C: Chapter 1

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C.1 Data Sources

- **Default Episodes:**
  Sovereign External Default and Restructuring 1800-2016 from Carmen Reinhart's Database at the Behavioral Finance and Financial Stability of Harvard Business School. The episodes do not take into consideration defaults on World War I debt to United States and United Kingdom but includes post-1975 defaults on Official External Creditors. There are five default episodes in the last 100 years for Brazil: 1914-1919, 1931-1933, 1937-1943, 1961-1964 and 1983-1994. https://www.hbs.edu/behavioral-finance-and-financial-stability/data/Pages/global.aspx
- **Central Bank Independence:**
  Central Bank Independence obtained from Garriga (2016).

- **Inflation:**
  Annual percentage of Average Consumer Prices on year-on-year changes from World Economic Outlook Database of International Monetary Fund.

- **Government debt as a % GDP :**
  Public External debt stocks as a percentage of GDP in International Debt Statistics from World Bank. Public and publicly guaranteed debt comprises long-term external obligations of public debtors, including the national government, Public Corporations, State Owned Enterprises, Development Banks and Other Mixed Enterprises, political subdivisions (or an agency of either), autonomous public bodies, and external obligations of private debtors that are guaranteed for repayment by a public entity. Data are in current U.S. dollars.
- **Expenses as a % GDP:**
  General government total expenditure in national currency as a % of GDP from World Economic Outlook Database of International Monetary Fund. Total expenditure consists of total expenses and the net acquisition of nonfinancial assets.

- **Spreads:**
  J.P. Morgan Emerging Markets Bond Spread (EMBI+). EMBIG series from World Bank Data.

- **Output:**
  Gross Domestic Product, constant Local Currency Unit from World Bank national accounts data, and OECD National Accounts data files.
- **Consumption:**
  Final Consumption Expenditure, constant Local Currency Unit from World Bank national accounts data, and OECD National Accounts data files.

C.2 Derivations

In this appendix we derive the optimality conditions of the monetary authority and the fiscal authority. We assume that all the policy functions are differentiable with respect to the state variables.

Given the state (y, b, b', i) the monetary authority solves the following problem:

$$\max_{\pi} \quad (1-i)u(c) - l(\pi)$$

subject to the resource constraint:

$$c = y - g + (1-D)q(y, b')\left(b' - (1-\delta)\frac{b}{\pi}\right) - (1-D)(r+\delta)\frac{b}{\pi}$$

where D takes the value 0 in states of repayment and 1 in states of default.

The first order condition with respect to π is given by:

$$l'(\pi) = (1-i)(1-D)u'(c)\left(r + \delta + (1-\delta)q(y, b')\right)\frac{b}{\pi^2}$$

In states of default this condition delivers (1.22), while in states of repayment it delivers (1.24).

In states of default, given the state y, the fiscal authority solves the following problem:

$$V_D^F(y) = \max_{i \in [0,1]} \quad u(c) - l(\pi) - \phi(y) - z(y, i) + \beta_F \mathbb{E}_{y'|y}\left[\theta V^F(y', 0) + (1-\theta)V_D^F(y')\right]$$

subject to (1.13) and:

$$\pi = \hat{\pi}_D^M(y, i)$$

The first order condition with respect to i is given by:

$$-l'(\pi)\frac{\partial \hat{\pi}_D^M}{\partial i} - \frac{\partial z}{\partial i} - \bar{\mu} + \underline{\mu} = 0$$

In states of repayment, given the state (y, b), the fiscal authority solve the following problem:

$$V_R^F(y, b) = \max_{i \in [0,1], b'} \quad u(c) - l(\pi) - z(y, i) + \beta_F \mathbb{E}_{y'|y}\left[V^F(y', b')\right]$$

subject to (1.15) and:

$$\pi = \hat{\pi}_R^M(y, b, b', i)$$

The first order condition with respect to i is given by:

$$u'(c)(r + \delta + (1-\delta)q)\frac{b}{\pi^2}\frac{\partial \hat{\pi}_R^M}{\partial i} - l'(\pi)\frac{\partial \hat{\pi}_R^M}{\partial i} - \frac{\partial z}{\partial i} - \bar{\mu} + \underline{\mu} = 0$$

Assuming that the solution is interior, $\hat{\mu} = \underline{\mu} = 0$, we obtain (1.25).
The first order condition with respect to b' is given by:

$$u'(c)\left(\frac{\partial q}{\partial b'}(b' - (1-\delta)\frac{b}{\pi}) + q\right) + u'(c)(r + \delta + (1-\delta)q)\frac{b}{\pi^2}\frac{\partial \hat{\pi}_R^M}{\partial b'} - \\ - l'(\pi)\frac{\partial \hat{\pi}_R^M}{\partial b'} + \beta_F \mathbb{E}_{y'|y}\left[(1-D')\frac{\partial V_R^F(y', b')}{\partial b'}\right] = 0$$

The derivative of the fiscal authority's value function with respect to b is given by:

$$\frac{\partial V_R^F(y, b)}{\partial b} = -u'(c)\frac{r + \delta + (1-\delta)q}{\pi} + u'(c)(r + \delta + (1-\delta)q)\frac{b}{\pi^2}\frac{\partial \hat{\pi}_R^M}{\partial b} - l'(\pi)\frac{\partial \hat{\pi}_R^M}{\partial b}$$

C.3 Proofs

Proof of Proposition 1. *Since the function $l(\pi)$ does not depend on the state (y, i), any change in the state (y, i) does not affect the best (interior) inflation response given by the equation $l'(\pi) = 0$. Hence, the best inflation response is not sensitive to changes in y and i.*

Proof of Proposition 2. *In state $D = 1$ the optimal independence level is given by* (1.23)*. Since the control cost $z(y, i)$ is decreasing in i, $\frac{\partial z}{\partial i} \leq 0$. If we consider the solution $i = 0$, $\bar{\mu} = 0$ and $\underline{\mu} > 0$, then* (1.23) *leads to a contradiction, hence $i = 0$ can not be a solution. If the solution is interior, i.e. $i \in (0, 1)$, $\bar{\mu} = \underline{\mu} = 0$, implying that $\frac{\partial z}{\partial i} = 0$, which is a contradiction, since $z(y, i)$ is decreasing in i. Finally, if we consider the solution $i = 1$, $\bar{\mu} > 0$ and $\underline{\mu} = 0$,* (1.23) *is satisfied. Hence, in state $D = 1$, the optimal independence level is 1, for each realization of y.*

Proof of Proposition 3. *Assuming that $u'(c) = 1$ we can write* (1.24) *as:*

$$l'(\pi) = (1 - i)(r + \delta + (1-\delta)q(y, b'))\frac{b}{\pi^2}$$

Using the implicit function theorem and assuming that $u''(c) = 0$ *we have the following derivatives:*

$$\frac{\partial \pi}{\partial i} = -\frac{(r+\delta+(1-\delta)q)\frac{b}{\pi^2}}{l''_{\pi\pi} + 2(1-i)(r+\delta+(1-\delta)q)\frac{b}{\pi^3}} < 0$$

$$\frac{\partial \pi}{\partial b} = \frac{(1-i)(r+\delta+(1-\delta)q)\frac{1}{\pi^2}}{l''_{\pi\pi} + 2(1-i)(r+\delta+(1-\delta)q)\frac{b}{\pi^3}} > 0$$

$$\frac{\partial \pi}{\partial b'} = \frac{(1-i)(1-\delta)\frac{\partial q}{\partial b'}\frac{b}{\pi^2}}{l''_{\pi\pi} + 2(1-i)(r+\delta+(1-\delta)q)\frac{b}{\pi^3}} < 0$$

$$\frac{\partial \pi}{\partial y} = \frac{(1-i)(1-\delta)\frac{\partial q}{\partial y}\frac{b}{\pi^2}}{l''_{\pi\pi} + 2(1-i)(r+\delta+(1-\delta)q)\frac{b}{\pi^3}} > 0$$

By assumption, the function $l(\pi)$ *is convex, hence* $l''_{\pi\pi} > 0$*. Moreover, since the default set increasing* b' *and decreasing in y,* $\frac{\partial q}{\partial b'} < 0$ *and* $\frac{\partial q}{\partial y} > 0$.

Proof of Proposition 4. If $z(y,i) = 0$ it is straightforward to see that $\frac{\partial z}{\partial i} = 0$ for all values of y and i. By replacing this condition in (1.25) we obtain the result in (1.26). In addition, by substituting (1.26) in (1.24) we obtain $i = 0$.

Proof of Proposition 5. If $i = 1$ we can observe that (1.24) is simply represented as $l'(\pi) = 0$. Since the function $l(\pi)$ does not depend on the state of the economy, it is straightforward to see that $\frac{\partial \hat{\pi}_M^R}{\partial b'} = \frac{\partial \hat{\pi}_M^R}{\partial b} = 0$. By replacing these results in (1.27) we obtain the result.

If $i = 0$ from Proposition 4 we know that $u'(c)(r+\delta+(1-\delta)q(y,b'))\frac{b}{\pi^2} = l'(\pi)$. This implies that both (b) and (d) cancel out, hence the result.

C.4 Computational Algorithm

The algorithm employed to solve the model is the following:

1. Construct a grid for the endowment y and bonds b;
2. Start with a guess for the bond price schedule $q_0(y,b') = 1$ for all (y,b')
3. Start with a guess for $V_{0,D}^F(y)$ and $V_0^F(y,b)$

4. Solve the monetary authority's optimization problem in state D for all (y, i) to obtain the reaction function $\hat{\pi}_D^M(y, i)$;
5. Solve the monetary authority's optimization problem in state R for all (y, b, b', i) to obtain the reaction function $\hat{\pi}_R^M(y, b, b', i)$;
6. Given $V_{0,D}^F(y)$ and $V_0^F(y, b)$, solve the fiscal authority's recursive problem using value function iteration and get the policies for default $\hat{D}(y, b)$, borrowing $\hat{b}(y, b)$; central bank independence $\hat{\imath}(y, b)$ and the value functions $V_D^F(y)$ and $V^F(y, b)$
7. Combine F's policies with M's reaction functions to obtain the policies for inflation in state D $\hat{\pi}_D(y)$ and in state R $\hat{\pi}_R(y, b)$;
8. Compute the bond price schedule using (2.28);
9. Use the value functions obtained in 6. and the bond price schedule obtained in 8. to repeat steps 4. to 8. until convergence is obtained.

C.5 Extensions

Model with no default option

Definition 3 (Markov Perfect Equilibrium) *A Markov perfect equilibrium for this economy is defined as:*

(i) a set of value functions $V^M(y, b)$ and $V^F(y, b)$;
(ii) policy functions for borrowing $\hat{b}(y, b)$, degree of central bank independence $\hat{\imath}(y, b)$, inflation $\hat{\pi}(y, b)$, and consumption $\hat{c}(y, b)$;
(iii) a bond price schedule $\hat{q}(y, b')$;

such that:

(a) Given the bond price schedule and the state (y, b, b', i), the reaction function $\hat{\pi}^M(y, b, b', i)$ solves the optimization problem (1.30)*;*
(b) Given the bond price schedule and the monetary authority's reaction functions, the policy functions $\{\hat{b}(y, b), \hat{\imath}(y, b)\}$ solve the optimization problem (1.32)*;*
(c) Given the bond price schedule, M's reaction function and F's policy functions, the policy functions for inflation is $\hat{\pi}(y, b)$;
(d) Given the bond price schedule and the other policy functions, $\hat{c}(y, b)$ satisfies the resource constraint;
(e) The bond price schedule satisfies (1.37)*, where $b'' = \hat{b}(y', b')$.*

Model with nominal downward wage rigidity

In this economy households consume a bundle of tradable goods c_T and non-tradable goods c_N, which are aggregated using the CES function[1]:

$$c = \left[\omega c_T^{-\mu} + (1-\omega) c_N^{-\mu}\right]^{-\frac{1}{\mu}} \tag{C.1}$$

where $\omega \in (0,1)$ denotes the contribution of the tradable good in the composite good c and $\mu > -1$ represents the elasticity of substitution between the two varieties.

In every period, households receive an endowment of tradable goods y_T, which follows the exogenous stochastic process:

$$log(y_T') = \rho_{y_T} \log(y_T) + \sigma_{y_T} \epsilon' \tag{C.2}$$

with $\rho_{y_T} \in [0,1]$ and σ_{y_T} denoting the persistence and the standard deviation of the stochastic process, respectively, and $\epsilon' \sim N(0,1)$.

At the margin, the price of tradable goods in terms of units of non-tradable goods p equates the marginal utilities between the two goods:

$$p = \frac{1-\omega}{\omega}\left(\frac{c_T}{c_N}\right)^{1+\mu} \tag{C.3}$$

The non-tradable good y_N is produced using labor h, supplied inelastically by households, with the production function $F(h) = h^{1-\alpha}$, where $\alpha \in (0,1)$. Following [47], production is subject to a nominal downward wage rigidity constraint. As in [32] this constraint is given by:

$$w \geq \frac{\bar{w}}{\pi_T} \tag{C.4}$$

where w is the real wage of the period, π_T is the inflation rate of the tradable goods and $\bar{w} > 0$ is a nominal constraint on wages.

The first order condition of the non-tradable producers satisfies:

$$w = (1-\alpha) p h^{-\alpha} \tag{C.5}$$

In equilibrium two conditions on h hold[2]:

$$h \leq 1 \tag{C.6}$$

$$h \leq \left[\frac{(1-\omega)(1-\alpha)\pi_T}{\omega \bar{w}}\right]^{\frac{1}{1+\mu(1-\alpha)}} c_T^{\frac{1+\mu}{1+\mu(1-\alpha)}} \tag{C.7}$$

[1] The tradable-non tradable aggregation is close to [47], [13] and [32]

[2] The first condition arises from inelastic labor supply, the second condition by combining the nominal downward wage constraint with the optimality condition of the non-tradable producer and the households' optimality condition.

The goods market clearing condition for non-tradable goods is given by $c_N = h^{1-alpha}$, while the goods market clearing condition for tradable goods is:

$$c_T = y_T + (1-D)\left(qb' - \frac{b}{\pi_T}\right) \tag{C.8}$$

where D denotes the default state of the period, as defined in the baseline model, q is the nominal price of the one-period[3] defaultable bond issued by the government, b and b' denote the current and future levels of bonds, respectively.

The problem of the monetary and fiscal authority authorities is identical to the benchmark model, with few exceptions. In this model, agents have disutility from π_T, instead of π[4], and the two authorities internalize the conditions (C.1), (C.2), (C.6), (C.7) and (C.8).

I denote with λ_1 the KKT multiplier associeted with (C.6) and λ_2 the KKT multiplier associeted with (C.7). Hence, labor h and tradable inflation π_T are determined by the following equations:

$$(1-i)c^{1+\frac{1}{\mu}-\sigma}(1-\alpha)(1-\omega)h^{-\mu(1-\alpha)-1} - \lambda_1 - \lambda_2 = 0 \tag{C.9}$$

$$\begin{aligned}\chi(\pi_T - \bar{\pi}_T) = &\underbrace{(1-i)c^{1+\frac{1}{\mu}-\sigma}\omega c_T^{-\mu-1}\frac{b}{\pi_T^2}}_{\text{(a)}} + \\ &+ \underbrace{\left[\frac{(1-\omega)(1-\alpha)\pi_T}{\omega\bar{w}}\right]^{\frac{1}{1+\mu(1-\alpha)}} \frac{c_T^{\frac{1+\mu}{1+\mu(1-\alpha)}}}{1+\mu(1-\alpha)}\frac{\lambda_2}{\pi_T}}_{\text{(b)}} \\ &+ \underbrace{(1+\mu)\left[\frac{(1-\omega)(1-\alpha)\pi_T}{\omega\bar{w}}\right]^{\frac{1}{1+\mu(1-\alpha)}} \frac{c_T^{\frac{1+\mu}{1+\mu(1-\alpha)}-1}}{1+\mu(1-\alpha)}\frac{b\lambda_2}{\pi_T^2}}_{\text{(c)}}\end{aligned} \tag{C.10}$$

As it can be seen from C.10, the left hand side represents the marginal cost of one extra unit of gross inflation, while the right hand side represents its marginal benefit, which can be decomposed in three terms. (a) represents the direct effect of diluting debt in terms of unit of tradable consumption; (b) represents the marginal benefit of relaxing the wage constraint C.4; (c) represents the marginal benefit of tradable inflation to increase the relative price p and shift resources from non-tradable to tradable consumption.

[3]For simplicity I assume that bonds are one-period in this alternative model.
[4]This can be thought as having disutility from exchange rate fluctuations.

Appendix D: Chapter 2

Arts & Sciences - Department of Economics

D.1 Data Sources

- **Total External debt as a % GDP :**
  Public External debt stocks as a percentage of GDP in International Debt Statistics from World Bank. Public and publicly guaranteed debt comprises long-term external obligations of public debtors, including the national government, Public Corporations, State Owned Enterprises, Development Banks and Other Mixed Enterprises, political subdivisions (or an agency of either), autonomous public bodies, and external obligations of private debtors that are guaranteed for repayment by a public entity. Data are in current U.S. dollars.
- **Local-Currency External Debt:**
  Local-Currency External Debt was obtained from the dataset compiled by [30].
- **Reserves as a % GDP:**
  Total Reserves in current US dollars (Indicator FI.RES.TOTL.CD) divided by Gross Domestic Product in current uS$ (Indicator NY.GDP.MKTP.CD) in World Development Indicators from World Bank. Total reserves comprise holdings of monetary gold, special drawing rights, reserves of IMF members held by the IMF, and holdings of foreign exchange under the control of monetary authorities. The gold component of these reserves is valued at year-end (December 31) London prices. Data are in current U.S. dollars.
- **Inflation:**
  Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used. Data source if from World Bank.
- **Central Bank Independence Index:**
  The Central Bank Independence Index (CBIE) constructed by [44] ranges from 0 (no independence) to 1 (full independence). The CBIE index considers 42 central bank characteristics over 6 dimensions[1] while including new criteria that accounts for good practices in central bank financial independence and reporting and disclosure.

[1]These dimensions are: (1) governor and central bank board, (2) monetary policy and conflict resolution, (3) objectives, (4) limitations on lending to the government, (5) financial independence and (6) reporting and disclosure.

D.2 Empirical Evidence

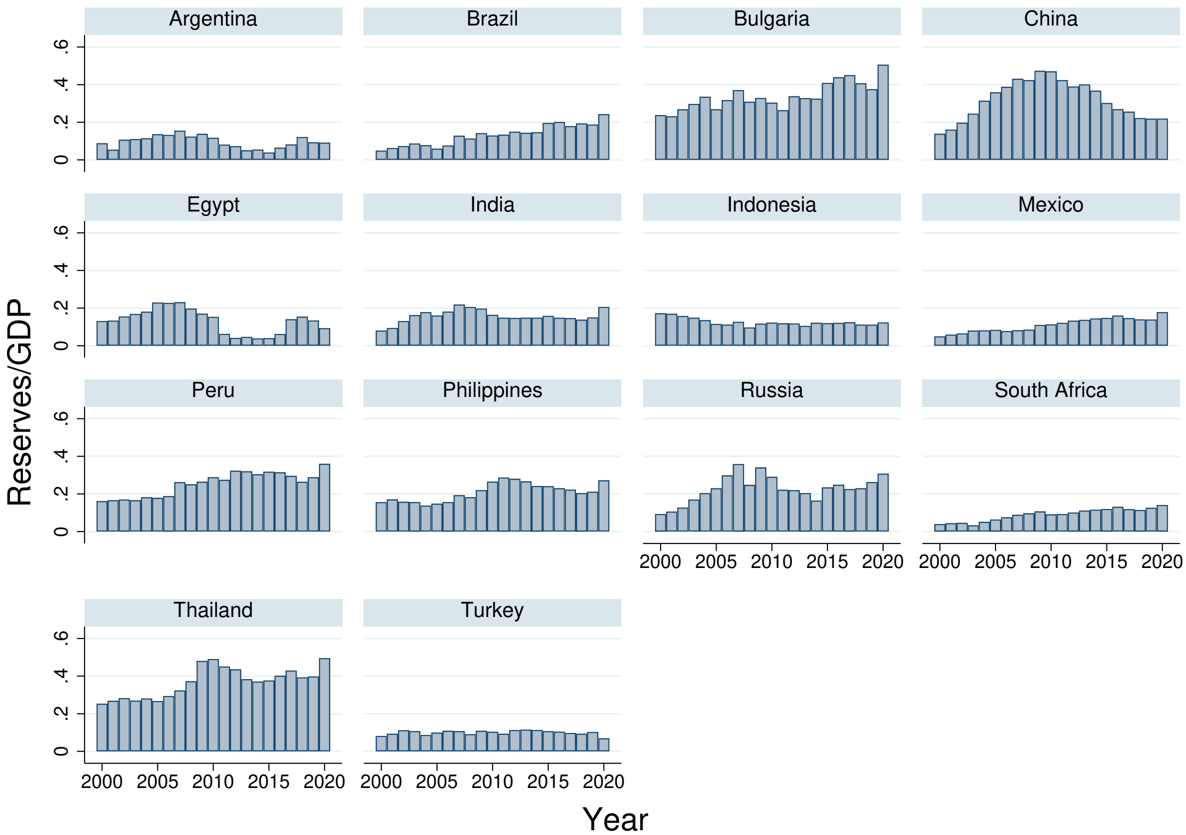

Figure D.1: International Reserves as % of GDP

Note: International Reserves as a % of GDP from World Bank for the period 1960-2020.

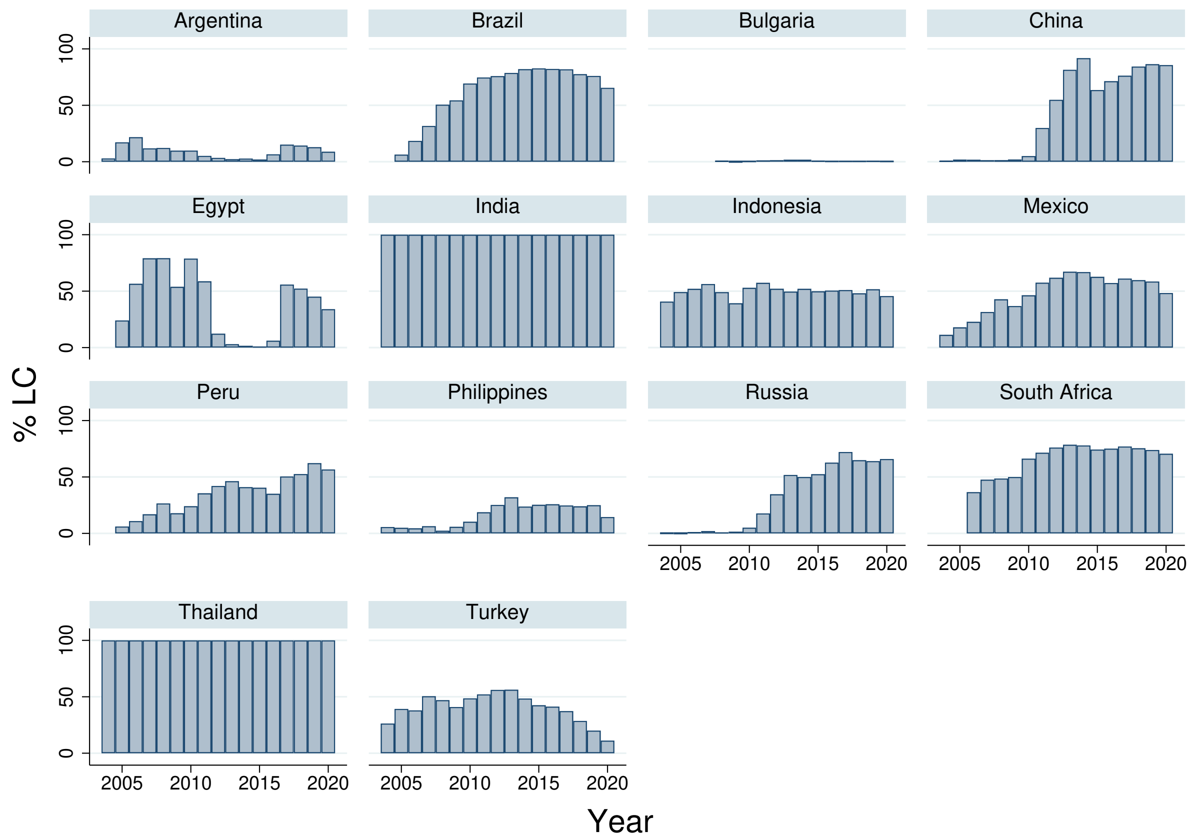

Figure D.2: Share of LC External Debt
Note: The share of debt in local currency (LC) corresponds to the share of external sovereign debt denominated in local currency over the period 2004–2014 due to the data availability of the database from [30].

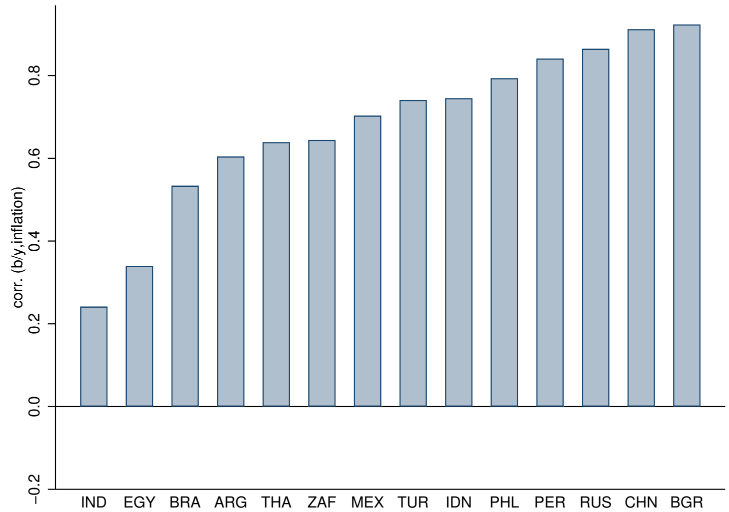

Figure D.3: Central Bank Independence and Inflation Correlation
Note: Central Bank Independence Index for 1972-2017 from [44] and annual average inflation from World Banks.

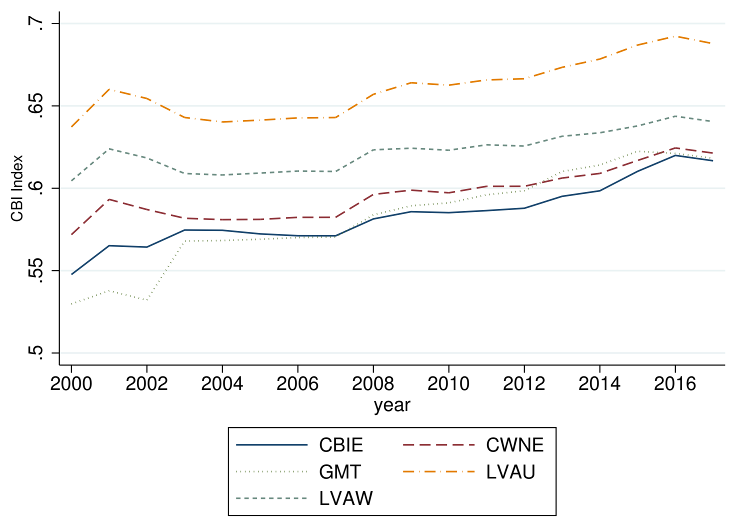

Figure D.4: Difference in CBI Indexes
Note: Different Central Bank Independence Indexes from [44] for 2000-2017. CBIE is the index elaborated by [44], GMT is the index from [46], LVAU and LVAW are the unweighted and weighted indexes from [45]; and CWNE [48].

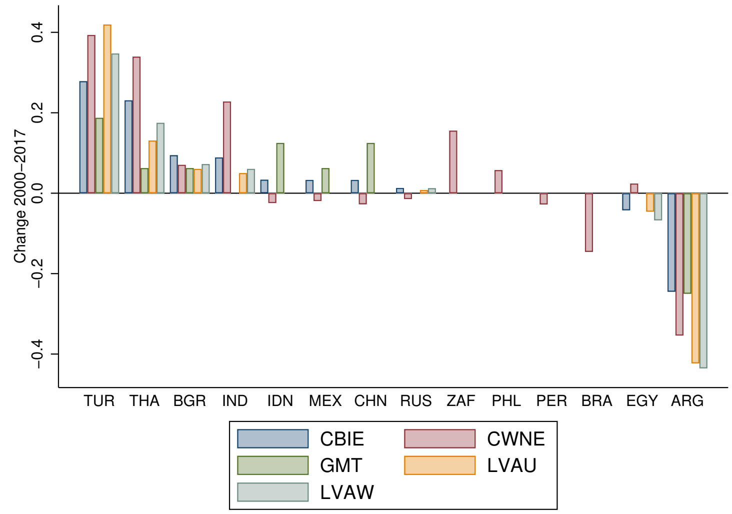

Figure D.5: Change in CBI of different Indexes by country
Note: Different Central Bank Independence Indexes from [44] for 2000-2017. CBIE is the index elaborated by [44], GMT is the index from [46], LVAU and LVAW are the unweighted and weighted indexes from [45]; and CWNE [48].